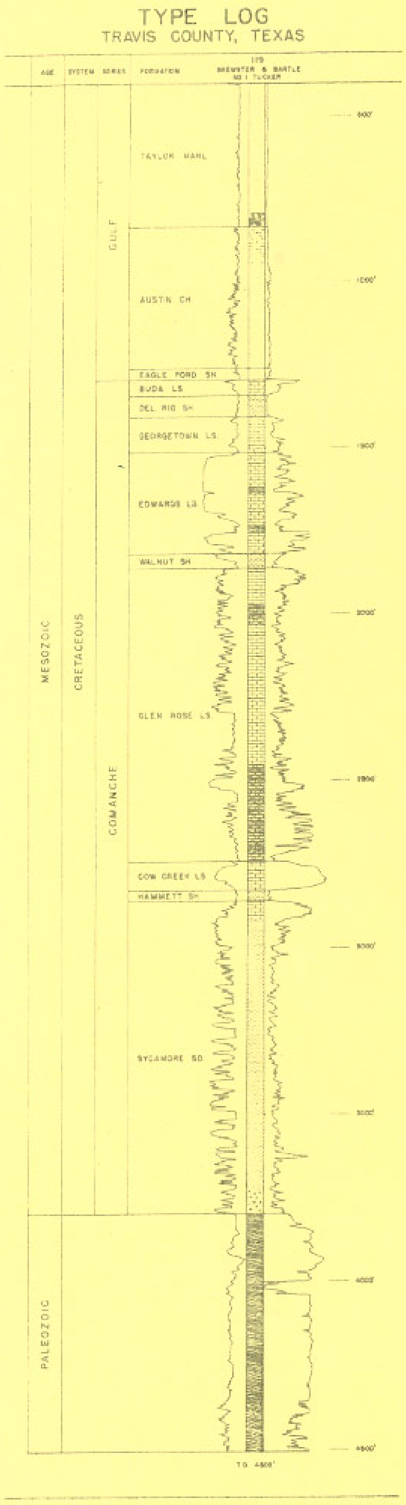


GUIDEBOOK To The GEOLOGY Of TRAVIS COUNTY

PUBLISHED by
THE STUDENT GEOLOGY SOCIETY
The University of Texas
1977

Guidebook to the Geology of Travis County: Preface

Geology of the Austin Area,

Travis County, Texas

Keith Young

When Robert T. Hill first came to Austin, Texas, as the first professor of geology, he described Austin and its surrounding area as an ideal site for a school of geology because it offered such varied outcrops representing rocks of many ages and varieties. Although Hill resigned his position about 85 years ago, the opportunities of the local geology have not changed. Hill (Hill, 1889) implies the intent of writing a series of papers to describe the geology of the local area for all who might be interested. The authors of this volume hope that they have fulfilled in large measure Hill's original intent.

No product can ever be all things to all users, but we have presented here common geological phenomenon for many, including the description of an **ancient volcano**, the **description of faulting that occurred in the Austin area** in the past, a **geologic history of the Austin area**, a **description of the local rocks**, including their classification, **field trips** for interested observers of the geologic scene, **collecting localities** for the lovers of fossils, and **resource places and agencies**.

We cannot emphasize enough that many unique geological phenomena are on private property. Please do not trespass, obtain permission. And if permission is not granted, observe from a distance. There are sufficient areas of geologic interest in the Austin area to please all without antagonizing landowners and making it even more difficult for the next person.

Guidebook to the Geology of Travis County: Author's Note

A useful guide to the geology of the Austin area has long been a goal. It should be useful to students, secondary school-teachers, and to any others with an interest in some aspect of geology. The many printings, several decades ago, of guide books to various aspects of the natural history of the Fort Worth area by Hortense and Professor W. M. Minton of Texas Christian University are ample proof of the popularity of such guides if properly done.

In 1973 several graduate students, Diana Grunig, M. A. Jordan, Donald F. Parker, and Bill Williams, suggested that they would be willing to aid in such a project if they could in some way receive credit for the work. This was arranged by enrolling them in Cretaceous Stratigraphy - Geology 380K. The present volume has resulted.

Not only should the above authors be acknowledged, but several students of The University of Texas at Austin Student Geological Society (SGS) have laboured to produce and publish an adequate format. Among them, Charles Stone edited and computerized the text, and, with the aid and instruction in the dark-room by John Pigott, edited the figures.

Keith Young
August, 1977

Guidebook to the Geology of Travis County: Web-Editor's Note

Egan Jones

This is, for the most part, the original 1977 publication of the "Guidebook of the Geology of Travis County." This was a fund-raising item for our student organization (USGS/AAPG/UTGS), but recently it seemed to be more of a hassle than a fund-raiser. The quality was also deteriorating, making copies of copies of copies... Something had to be done.

With the recent changes in information accessibility in the form of the Internet and World-Wide-Web, and the demand for this geologic guidebook, a request was made to translate it to HTML, so that it could be easily accessed by everyone. In translating the guidebook to HTML, many of the items have become outdated (especially in the **Austin Area Geology Resources**). I wanted to try to keep this as true to the original as possible. This includes the book-like format (easily accessed from the **Table of Contents**) as well as many of the figures. Unfortunately, being true to the original has its side effects. The poor quality and legibility of some of the figures was improved as much as modern technology could permit, aside from completely redrawing them (it was considered!). Easily accessed larger figures was the final solution to the legibility problem.

I would like to thank Dr. Young for lending me the "most legible" copy available and Dennis Trombatore for his ideas, feedback, and help in translating this work. Dennis informs me that this is quite possibly the first on-line geologic guidebook. It is but a small step toward getting many useful books and materials Internet-ready so that they can be accessed worldwide.

So, what you have in your hand (or rather - on your screen) is the finished version of the guidebook. So please . . .

Enjoy and Learn!
Egan Jones
September 30, 1996

Table of Contents

Chapters

Appendices

Table of Illustrations

Guidebook to the Geology of Travis County

Chapter 1: The Geologic History of the Austin Area

Diana Grunig

The geologic history of any area is interpreted by studying its rocks and fossils. Where those rocks and fossils do not outcrop, the history of the area may be interpreted, though only broadly, by extrapolating data from other areas and by studying samples brought from deep in the ground by tests drilled for oil or water. In the Austin area the older rocks are not exposed, and the historical interpretation of those more ancient times is less exact.

THE PRECAMBRIAN ERA

(up to 600 million years ago)

Not much is known of the Precambrian history of the immediate Austin area. Precambrian rocks do not crop out in Travis County, and the deepest rocks that have been reached by drilling can be identified as Paleozoic or as metamorphic rock of undetermined age. To the northwest, in the nearby Llano region, outcrops expose rocks rich in history -- a sequence of events including (1) deposition of sedimentary and volcanic debris in a broad basin, (2) deformation of the lithified sediments by faulting and folding, (3) metamorphism of the deformed rocks and their intrusion by igneous rock bodies, and finally, (4) the intrusion of large granitic masses about a billion years ago. The processes of faulting, folding, and intrusion recorded in the Llano rocks must have built a mountain range there, but the effects of nearby Precambrian mountains are not recorded in the much younger rocks of the Austin area. The next 400 million years saw the destruction of the mountain range by erosion. (For a more detailed picture of the geologic history of the Llano region, a good start is Guidebook 13, by Barnes and others, 1972, published by the **Bureau of Economic Geology**, University of Texas at Austin).

THE PALEOZOIC ERA

(from 600 million to 225 million years ago)

During the Paleozoic Era the Austin area was part of the Ouachita Geosyncline, the rocks of which were folded and faulted into an ancient mountain range in the late Paleozoic (**Figs. 1**, **2**). The Ouachita system of rocks stretched in a broad and gentle arc from the Ouachita Mountains, for which they are named, in Arkansas and Oklahoma, across Travis County, to Texas' Big Bend region and in the Marathon Uplift, but they are known only from well data in intervening areas. Paleozoic rocks on the edge of the geosynclinal basin, updip from the strata that underlie the Austin area, are exposed in the Llano region to the northwest.

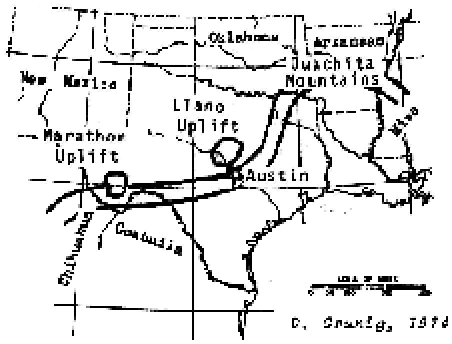


FIGURE 1
Location of Ouachita Structural Belt (36K)

Figure 1
Location of Ouachita Structural Belt

Rocks of early Paleozoic age are known from the Llano region, in outcrops, and in wells just to the southeast of the outcrop area. They record a time of principally shallow marine shelf and shoreline environments of deposition, with both clastic and carbonate sediments. Early Paleozoic time in the Austin area was probably similar to this, though by the start of the Ordovician time, the Ouachita geosyncline trough may have been established; with the existence of the Ouachita trough, sedimentary deposits in the Austin area became relatively thicker than in the Llano region, and deposition may have been in relatively deeper water.

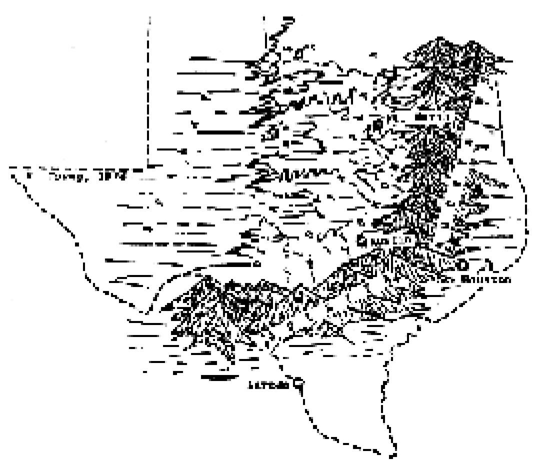


Figure 2
Central Texas in the Upper Pennsylvanian (54K)

Figure 2
Central Texas in the Upper Pennsylvanian

Through middle and late Paleozoic time great volumes of sediments were deposited in the Ouachita trough. During Pennsylvanian time these geosynclinal sediments were compressed, deformed, and uplifted into a great mountain range. These mountain ranges supplied sediment to the flanking seas. By the end of the Paleozoic the period of Ouachita mountain building was over. The seas no longer covered the Austin area. The region was underlain by folded Paleozoic rocks to the northwest and metamorphic rocks to the southeast. **Figure 3** shows the extent of known Paleozoic rocks in the Austin area.

THE TRIASSIC AND JURASSIC PERIODS OF THE MESOZOIC ERA

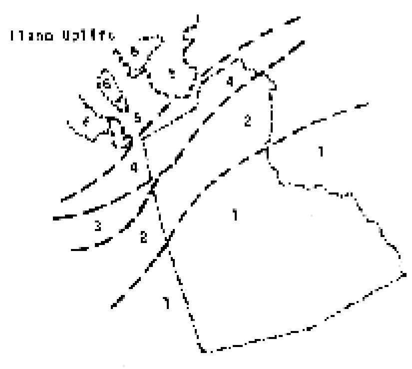
(225 million to 136 million years ago)

No known rocks from the first part of the Mesozoic Era remain in the Austin area or in nearby Llano. The whole region was probably a land area, and erosion the dominant geologic activity of the time. As the old Ouachita mountain belt was being reduced to lowlands, the area to the southeast began to subside to form the Gulf of Mexico geosyncline. To the southeast of Travis County, Jurassic rocks are encountered in deep wells.

THE CRETACEOUS PERIOD OF THE MESOZOIC ERA

(136 million to 65 million years ago)

Most of the rocks that crop out in the Austin area are Cretaceous. In brief, the history of the Cretaceous Period in the Austin area is the story of gradual though intermittent northwestward encroachment of the sea that filled the subsiding Gulf of Mexico geosyncline to the southeast.



(23K)

Figure 3
Paleozoic Rocks, Austin Area
(Simplified from Flawn et.al., 1961)

1-Metamorphic rocks, subsurface, Paleozoic and Precambrian
2-Rocks of the Ouachita Geosyncline, subsurface, Mississippian through Pennsylvanian
3-Rocks of the Ouachita Geosyncline, subsurface, Cambrian through Devonian

4-Rocks of the shelf and the margins of the Ouachita Geosyncline, subsurface, Mississippian through Pennsylvanian
5-Rocks of the shelf and the margins of the Ouachita Geosyncline, outcrop, Mississippian through Pennsylvanian
6-Rocks of the shelf and the margins of the Ouachita Geosyncline, outcrop, Cambrian through Devonian

Earliest Cretaceous time is recorded in rocks of the Trinity Group of the Commanchean Series. The generalized paleogeographic setting for the deposition of these rocks is shown in **Figure 4**. The eroded lowland over which the Cretaceous sea encroached, was not flat, and local differences of relief add to the complication of interpreting Cretaceous events. The Sycamore Conglomerate, the oldest formation of the Trinity Group, probably represents the fluvial systems that fed the first marine Cretaceous sediments into the Gulf of Mexico geosyncline (the Hosston and Sligo Formations, found in the subsurface to the southeast of the Sycamore Conglomerate). After a period of slight uplift and erosion, the Hammett Shale and the Cow Creek Limestone were deposited on the older Sycamore Conglomerate and on Paleozoic surface to the northwest. The Hammett Shale and Cow Creek Limestone marine shale and some marine sandstones and conglomerates; the second comprises, in many places, a cross-bedded beach rock. After a period of erosion of the upper Cow Creek Limestone, the Cretaceous sea once again deposited sediments on underlying older Cretaceous rocks and encroached on the remaining exposed Paleozoic surface to the northwest. The Hensel Sandstone and the **Glen Rose Limestone** were deposited during this time. The Hensel Sandstone represents fluvial, tidal, lagoonal, beach, and nearshore marine environments, the marginal deposits of the northwestward-advancing sea. The **Glen Rose** rocks represent sediments deposited on a very large, very shallow marine shelf. Outcrops around Austin show a wealth of interfingering carbonate environments, changing in time and space, from subtidal lagoonal flats, to shoals, to beaches, to marshes and ponds at or just above sea level. The youngest rocks of the Glen Rose contain many indications of very shallow-water and supratidal environments of deposition, including evaporates, dinosaur tracks, and mud cracks.

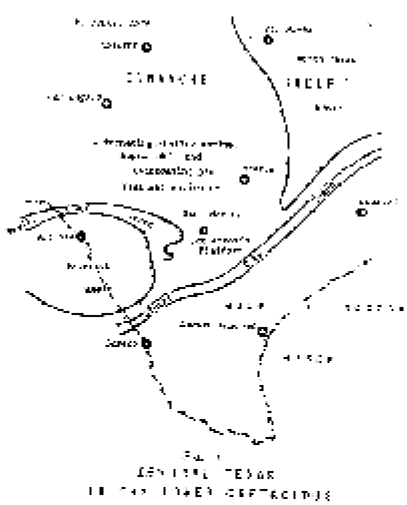

(47K)

Figure 4
Central Texas in the lower Cretaceous

The **Walnut Formation** of the Fredricksburg Group was deposited on the **Glen Rose Limestone**. The contact between these two formations in the Austin area is not erosional, as it is in the Llano region, but the very uppermost Glen Rose has been bored by marine mollusks, indicating lithification of the Glen Rose and the return of a marine environment before the deposition of the Walnut. The oldest Walnut rocks contain some terrigenous clastic material, clay and sand-sized limestone grains, probably brought in from the northwest. This is the **Bull Creek Member** of the Walnut Formation. Overlying this is the **Bee Caves Member**, followed by the Cedar Park Member which represents the rapid advance of a marine marsh environment. Next came deposition from a sequence of alternating marine marsh and open marine environments (the upper clays of the Walnut Formation), extending as far south as an oolite bar (the Whitestone Lentil) which developed across the northern part of Travis County. These formations are overlain by the youngest formation of the Fredricksburg Group, the Edwards Limestone, which was deposited from a northwesterly transgressing sea. The geography of the Austin area during the time of deposition of the Edwards may have looked like **Figure 5.**

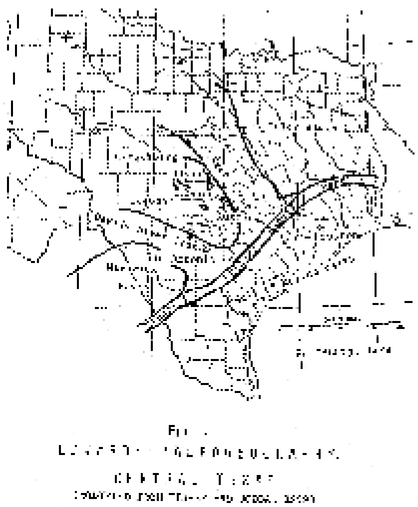

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Figure 5
Edwards Paleogeography, Central Texas
(MODIFIED FROM FISHER AND RODDA, 1969)

The encroaching Cretaceous seas had by this time covered almost all of the Llano uplift, and marine circulation was still restricted by the development of large reef trends. The Edwards Limestone is composed of rocks from medium- to high-energy, shallow-water, marine environments reefs and flank deposits of reef detritus, oolite shoals, inter-reef deposits of carbonate mud and sand, and lagoonal carbonate mud and sand, and lagoonal carbonate mud and evaporates in the Kirschberg area, plus many associated supratidal rocks.

The Washita Group, the last of the Comanche Series, was deposited on top of the Edwards Limestone. By this time the remaining islands in the Llano region had been drowned, and the Cretaceous sea in Texas was part of the sea that stretched all the way to the Arctic and was known as the Cretaceous Rocky Mountain Geosyncline. The San Marcos Platform was still a controlling feature of Cretaceous topography, and the formations of the Washita Group are thinner in the Austin area than they are in the nearby Tyler and Maverick basins. The oldest unit, the Georgetown Formation, consists of shaly limestone and fine-grained limestone deposited in shallow marine waters. Above this, the Del Rio Formation is a shale from a restricted marine shelf environment, and the overlying Buda Limestone is also thought to have been laid down on a broad, low energy, shallow, shelf behind the Stuart City Barrier Reef.

Following the floundering of the Stuart City Barrier Reef, the Gulf Series of the Cretaceous in the Austin area was inaugurated by the deposition of the terrigenous sediments of the Woodbine and Eagle Ford Groups. The detrital material introduced into this carbonate system was probably derived from the Ouachita Mountains in Arkansas and to the east, since following the drowning of the last of the Llano islands, there was no nearer source.

Carbonate deposition returned to the area with the deposition of the Austin Group, locally known as the Austin Chalk. Austin Group sediments were deposited in shallow and near-shore marine environments. Some of the topographic highs that controlled the distribution of those environments were provided by a belt of volcanoes which erupted in the Austin area and to the south and west, interlayering lava flows, volcanic ash beds, and wave-reworked volcanic material with the carbonate sediments.

The Taylor Group, which was deposited next, is a marine calcareous clay, and the Navarro Group, the last of the Cretaceous, consists of marine marl and carbonaceous shale.

THE CENOZOIC ERA

(65 million years ago to present)

The Cenozoic history of the Gulf of Mexico geosyncline is dominantly the story of gradual withdrawal of the seashore to its present position, accompanied by the deposition and distribution of marine sediments, then sediments deposited by deltaic and shoreline processes and finally terrigenous sediments deposited by fluvial systems. Each successively younger fluvial system is farther to the southeast than the last. The Austin area, already on the margin of the geosyncline at the start of the era, was not an area of major sedimentary deposition during the Cenozoic. Possibly it was a site of deposition in the Paleocene (the earliest Cenozoic); by Oligocene (about middle Cenozoic), the area may have been on a low land area, a minor contributor of sediment in the Gulf. In the next epoch, the Miocene, the major movement along the Balcones Fault Zone began, in the belt where volcanoes of the late Cretaceous had stood. Any earlier-deposited Cenozoic sediments and the upper Cretaceous rocks began to be eroded from the Austin area. Northwest of the fault zone, on the upthrown side, erosion continued until today the lower Edwards Formation is the youngest rock unit exposed. In the fault zone, younger rock units are preserved in down-dropped fault blocks. Southeast of that, the undisturbed updip ends of the very gently-dipping late Cretaceous and Cenozoic formations make broad bands of outcrops, each band younger than the last as you go southwest towards the coast.

Onto this general picture the geologic processes of the most recent period, the Quaternary (beginning up to 2 or more million years ago), have superimposed only the dissection of the edge of the upthrown fault block by the Colorado River and other streams, and the deposition of broad, thin, fluvial terrace deposits on the plains of the downthrown block.

Guidebook to the Geology of Travis County

Chapter 2: Rocks of the Austin Area

Keith Young

The Austin area has a great variety of interesting rocks. However, one must go to the Llano Uplift for the oldest rocks in Texas and to the Gulf Coast for the youngest. The following discussion is restricted mostly to the rocks that occur in Travis County or an area of greater Austin.

The discussion below will describe the various formations in and around Austin with the aid of maps and illustrations. **Figure 6** serves as a guide towards indicating the lithologic symbols that will be used in the stratigraphic sections found below in this chapter.

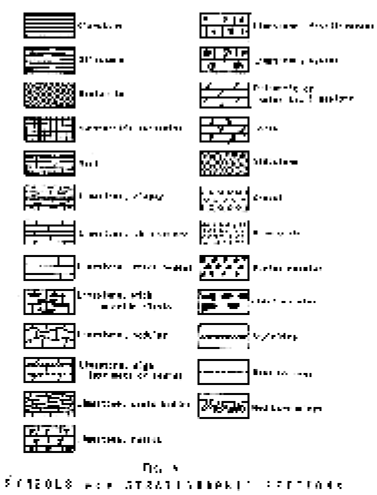

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Fig. 6
Symbols for Stratigraphic Sections

GLEN ROSE LIMESTONE

In the Austin area the Glen Rose Limestone is restricted to the northwest side of the Mount Bonnell Fault, where it is in immediate contact with other formations southeast of the fault. The formation crops out from just north of Northland Drive along the west side of the fault to Huck's Slough just east of Mount Bonnell, and then crosses the Colorado River as the fault crosses to the southwest side of the river. West of the fault Glen Rose is exposed, except on the highest hills. Fredricksburg rocks crop out on the northwest side of the fault from just north of Northland Drive to as far north as Georgetown, and are generally in contact with other formations on the southeast side of the fault.

Lithology - The Glen Rose Limestone **(Fig. 7)**, particularly the upper part exposed in the vicinity of Austin, consists of alternating beds of harder and softer limestones (mostly biomicrite). The harder beds are more cemented than the softer beds, and are usually thinner than the softer beds, which are marly, consisting of slightly clayey limestone. There are a few harder beds of organic debris or organic growth, the latter usually biolithites.

The Glen Rose Limestone thickens from northwest to southeast in the Austin area, but since the lower part is not exposed, the thickening and thinning is not readily apparent.

Boundaries - In the subsurface of the Austin area the Glen Rose rests disconformably on the Cow Creek Limestone, and there is no Hensel Formation. To the north of the Austin area, the base of the Glen Rose Limestone is gradational with the Hensel Formation, the Hensel being the nearshore lateral terrigenous equivalent of a part of the Glen Rose Limestone.

The Walnut Formation overlies the Glen Rose Limestone. The upper surface of the Glen Rose Limestone in the Austin area is bored by rock-boring pelecypods (Lithophaga sp. and Gastrochaena sp.), indicating that this surface was a hard ground before the deposition of the ensuing formation. Prior to boring and before hardening, dinosaurs sometimes tramped across this surface. This surface has been said to be an erosional surface, but the evidence is debatable. The most marked difference between the upper part of the Glen Rose and the lower part of the **Walnut** is the hypersaline depositional aspects of the former and the brackish water aspect of deposition of the latter.

Environments of deposition - The Glen Rose was deposited behind (northwest of) the Stuart City reef trend **(Fig. 4)** and represents a variety of shallow subtidal to supratidal environments; in the Austin area the great preponderance of rock was formed under supratidal conditions. The source of the carbonate sediment was from subtidal organic accumulations of carbonates, which were in turn reworked into supratidal environments by storms, winds, and waves.

Localities - The Glen Rose Limestone can be studied at Mount Bonnell **(Fig. 7)** and along the new road cuts on the West Loop between the Colorado River and Westover Hills. Other good localities can be visited along the Marble Falls highway (Highway 71) between Oak Creek and Barton Creek.

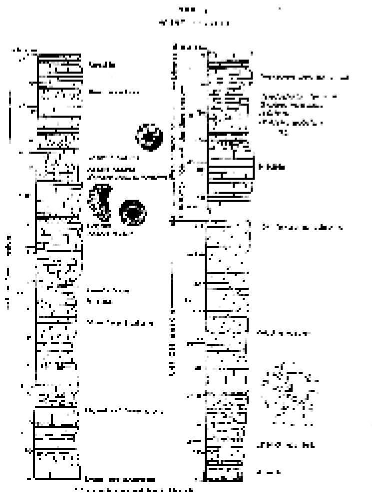

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Figure 7
Mount Bonnell

WALNUT FORMATION

In the Austin area the Walnut Formation is restricted to the northwest side of the Mount Bonnell Fault, where, south of the Colorado River, it occurs on the tops of the hills. On the north side of the Colorado River, the Walnut Formation can be found on Mount Barker, along the sides of hills in Northwest Hills, and around the edge of the Jollyville Plateau.

The Walnut Formation is comprised of two members in the Austin area, the **Bull Creek** below and the **Bee Caves** above.

Bull Creek Member
Lithology- The Bull Creek Limestone, lowest member of the Walnut Formation, comprises about 11.5 to 13 meters (35 to 40 feet) of hard limestone. The lowest bed is a nodular biomicrite, softer at the base and becoming sparitic toward the top. This is followed by from three to five cycles of the same description, the last of which is capped by a hard biosparite (grainstone) that represents the top of the Bull Creek.

Boundaries - The lower boundary has already been described. The upper boundary of the Bull Creek limestone is a bored bed (Lithophaga and Gastrochaena spp.) of hard ground on the uppermost biosparite mentioned above.

Environments of deposition - Moore (1961) interpreted the Bull Creek area of deposition as a lagoon. The cycles represent cycles of subtidal deposition, each prograding, and the bed at the top of the last cycle probably represents intertidal shoaling.

Localities - The Bull Creek Limestone Member of the Walnut Formation can be observed in the hills on the West Loop between St. Stephen's School and Bee Cave Road, and along West Loop just west of Westover Hills (Fig. 8).

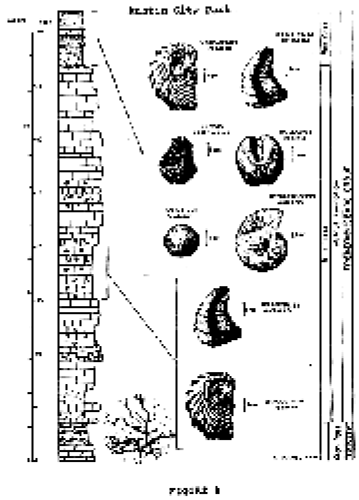

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Figure 8
Austin City (Emma Long) Park

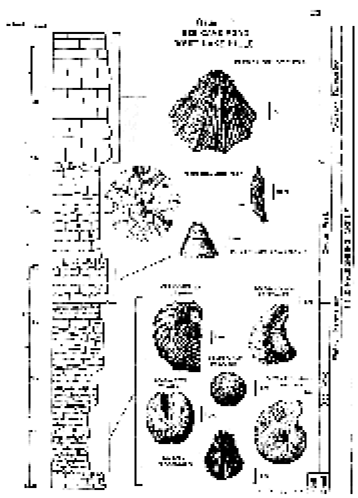

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Figure 9
Bee Caves Road, Westlake Hills, TX

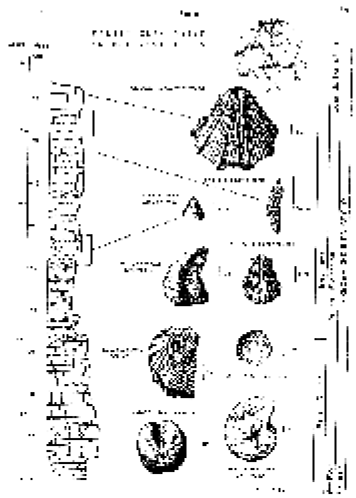 **(BIGGER)**

Figure 10
Walnut Clay Drive, in Northwest Hills

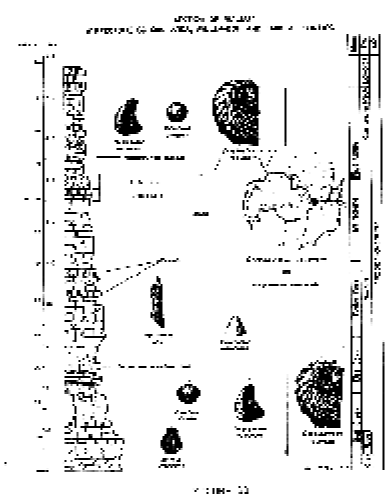 **(BIGGER)**

Figure 11
Section of Walnut
Whitestone School Area, Travis and Williamson Counties

Bee Cave Member
Lithology - The Bee Cave Member is a marly limestone (slightly clayey limestone or slightly clayey biomicrite) from 10 to 15 meters (30 to 45 feet) thick, overlying the Bull Creek Member. The maximum clay content in any one bed is about 30 percent, but clay content seldom exceeds 15 percent. The member contains beds from 5 to 15 centimeters or more in thickness of shells of *Texigryphaea mucronata* (Gabb) and *Ceratostreon texanum* (Ršmer) (respectively the common "Gryphaea" and "Exogyra" texana of the Fredricksburg formations of Texas). The member becomes 'less clayey' upward.

Environments of deposition - Moore (1961) also interprets the Bee Cave Marl as deposited in a lagoon behind barriers, but with a small source of fine terrigenous sediment that was not available during Bull Creek deposition. The deposit represents mostly subtidal to intertidal grassflats, becoming more calcareous upward.

Localities - The best locality to observe the Bee Cave Member is along the road to City Park at the top of the hill. It also crops out on Bee Cave Road just west of the south end of Red Bud Trail (but watch the traffic), and along Red Bud Trail east of St. Stephen's School (Figs. 8, **9, 10**, and **11**).

EDWARDS LIMESTONE

The Edwards Limestone lies mostly to the north and west of the Balcones Escarpment. It is the hard limestone which, because it weathers slowly, holds up the Balcones Escarpment through most of the area. It also crops out over a large area in the Jollyville Plateau.

Lithology - The Edwards Formation consists of about 90 to 105 meters (300 to 340 feet) of various kinds of limestone. Most of the Edwards in the Austin area consists of the lowest member, which is about 60 meters (200 feet) thick and consists of dolomite, dolomitic limestone, and hard, gray limestone containing rudists (long, conical bivalves; Fig. 12). Gray to black chert is common.

Member 2 of the Edwards Limestone is about 12 meters (40 feet) of thin bedded, fine-grained, dolomitic limestone, and fine-grained flaggy limestone. Nodular chert is common.

Member 3 of the Edwards Limestone consists of mostly soft, burrowed limestone (micrite) that forms a marly slope. It is from 3 to 5 meters (10 to 15 feet) thick.

Member 4 of the Edwards Limestone is the uppermost member and is about 12 meters (40 feet) thick. It consists of flaggy limestone beds, and a 1-meter thick rudist bed overlain by dolomitic limestone. Its top is a calcarenitic limestone with sparse gluaconite grains.

Boundaries - Both boundaries of the Edwards Limestone in the Austin area are gradational, the Lower Edwards gradually grades into Walnut beds to the north, and the uppermost Edwards Limestone grading into Georgetown beds to the north.

Environments of Deposition - The rocks of the Edwards Limestone represent deposition in a great variety of carbonate environments; reef, lagoonal, shoal, basinal, and supratidal environments of deposition are represented. In addition, many of the limestones thus deposited were altered to dolomite by the invasion meteoric waters shortly after deposition. In the Austin area, along the Balcones fault zone, some dolomitization occurred later, following the invasions of waters high in magnesium sulfate.

Localities - The Edwards Limestone can be observed along the Colorado River below Tom Miller Dam (Fig. 12) and at many localities above Barton Springs on Barton Creek.

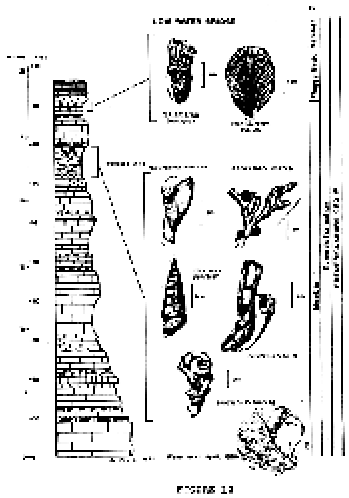

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Figure 12
Low Water Bridge near Red Bud Island

GEORGETOWN FORMATION

The Georgetown Formation crops out in discontinuous patches that have been interrupted by faulting. Most of these outcrop areas are just southeast of the Mount Bonnell fault.

Localities - Most of the Georgetown Formation consists of alternating beds of thin, fine-grained limestone or marly limestone (biomicrite or marly biomicrite = wackestone or marly wackestone). The nearly complete section of Georgetown Formation that was once exposed in the railroad cut at Sixth Street (Fig. 13) has since been removed by the development of Mopac Boulevard, but parts of the formation can still be observed in Johnson Branch and other nearby areas. The Georgetown Formation ranges from 13 meters (40 feet) in thickness in the Rollingwood area to about 20 meters (60 feet) near McNeil, north of Austin, the lower part being replaced by Edwards Limestone to the south.

Environments of deposition - The Georgetown Limestone represents a number of open-shelf, subtidal environments that are differentiated primarily by the faunas that occupied the different environments.

Localities - The top of the Georgetown Limestone can be observed in Shoal Creek at about Martin Luther King Jr. Street (19th Street) (Fig. 14); the formation can also be seen in Johnson Branch and nearby localities near the Sixth Street access to Mopac Boulevard, north of Mount Bonnell Road in Huck's Slough, where it is in fault contact with the Glen Rose Limestone, and in an area known as "Fossil Valley" in Rollingwood.

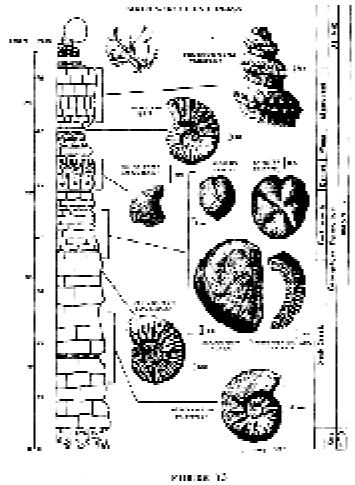 (BIGGER)

Figure 13
Sixth Street Underpass

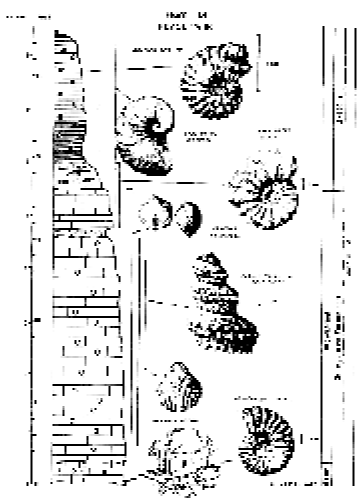 (BIGGER)

Figure 14
Pease Park

DEL RIO CLAYSTONE

The Del Rio Claystone is a formation that crops out in more or less discontinuous areas along Shoal Creek as the result of faulting in Barton Hills and along Barton Springs Road. It is a shrink-swell clay, and because of this, successful construction of building and streets on the Del Rio requires special engineering designs.

Localities - The Del Rio is about 25 meters (75 feet) of dark olive to bluish-gray to yellow-grown pyritic, gypsiferous clay. The clay contains illite, montmorillonite, and kaolinite. Ilymatoqyra arietina (Ršmer), sometimes mentioned as "E arietina by authors, commonly occurs within this for

Boundaries - The lower boundary of the Del Rio is gradational with the Georgetown Limestone, and the transition occurs through one to two meters (several feet). The upper boundary in the Austin area is scoured by, and therefore disconformable with, the basal beach limestone of the Buda Formation.

Environments of deposition - The Del Rio Claystone contains many very small species, and lacks a normal bottom assemblage. It is therefore interpreted to have been deposited in a lagoon with abnormal bottom conditions, as indicated by the large amounts of pyrite. Upon weathering, the pyrite reacts with water to produce sulfuric acid, which in turn reacts with calcite to produce the selenite (crystalline gypsum) that occurs in the weathered zone.

Localities - The Del Rio can be observed along Shoal Creek. It can best be observed along Barton Springs Road.

BUDA LIMESTONE

The Buda Limestone crops out in a series of discontinuous areas in the fault zone. These are separated by faulting and erosion.

Localities - The Buda Limestone consists of 11.5 to 16 meters (35 to 50 feet) of nodular, soft and hard limestone (biomicrite and biosparite). The basal bed is a hard limestone composed of oyster shell fragments (oyster shell biosparite or grainstone). Most of the other beds are mollusk limestones softer in the lower part and harder in the upper part (nodular mollusk biomicrites and biosparites or wackestones and packstones).

Boundaries - The lower boundary is locally disconformable, and the upper boundary is disconformable over a broad area. This upper disconformity represents the time during which many formations of the Woodbine Group were being deposited to the north of Austin. The only representative of this group in the Austin area is the Pepper Shale Member of the Eagle Ford Formation, which immediately overlies the broad unconformity.

Environments of deposition - The Buda Limestone in the Austin area represents shallow subtidal and intertidal deposits. The basal limestone represents a shell or shoal of beach that transgressed across the Del Rio Formation and scoured it at the top. The rest of the Buda represents shallow subtidal storm deposits; the different beds seem to have been reworked by storms many times, and most of the fossils have been broken. However, burrowing animals can still be collected.

Localities - The Buda Limestone can best be visited at a variety of outcrops along Shoal Creek (Fig. 15), especially along the Hike and Bike Trail, along Barton Springs

Road at South Lamar (Fig. 16), along Bear Creek just below the old Manchaca-Buda road crossing, and at the Manchaca Road crossing of Williamson Creek (Fig. 17).

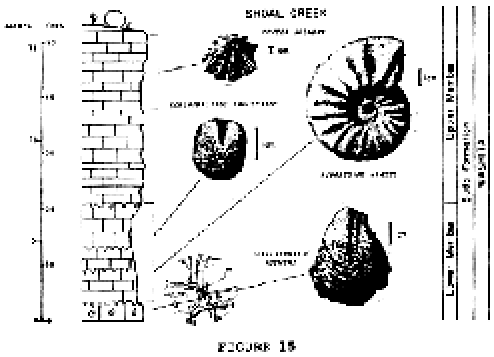

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Figure 15
Shoal Creek at Town Lake

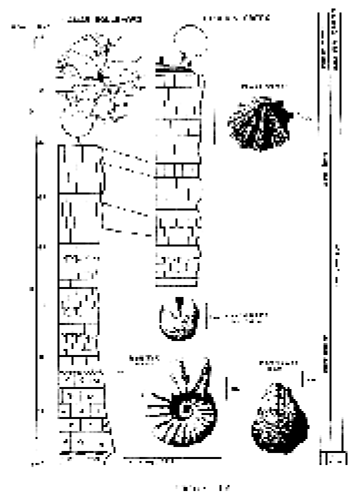

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Figure 16
Bouldin Creek at S. Lamar Blvd.

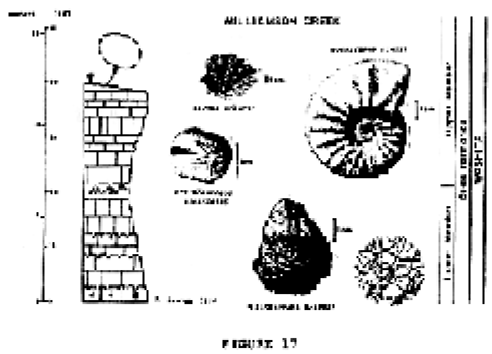

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Figure 17
Williamson Creek

EAGLE FORD FORMATION

The Eagle Ford Formation in the Austin area is also extensively faulted and crops out in a series of more or less discontinuous areas between Shoal Creek and Lamar Boulevard in north Austin (Fig. 18). Through much of Austin the formation is covered, but most of it can be seen in the drainage ditch and along West Bouldin Creek between Barton Springs Road and Milton Street (Figs. 19 and 20). The Eagle Ford is comprised of four members in the Austin area: from bottom to top, the Pepper Shale, the Cloice Shale, the Bouldin Flags, and the South Bosque Marl.

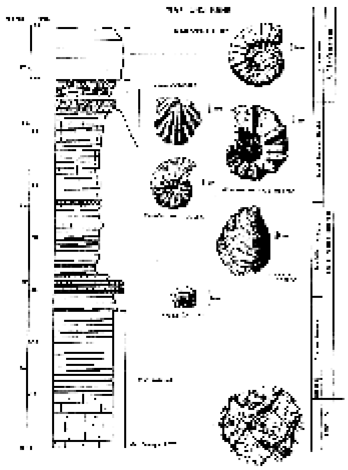
FIGURE 18 (BIGGER)

Figure 18
Watters Park

Pepper Shale Member

Localities - The Pepper Shale is a black, unctuous (soapy) or greasy claystone composed mostly of montmorillonite, sometimes stained yellowish with jarosite and containing selenite. The Pepper is probably the least stable rock unit in Texas, but fortunately, it is only 1 to 1.8 meters (3 to 5 feet) thick in Austin.

Boundaries - Both boundaries of the Pepper Shale, the only part of the Woodbine Group in the Austin area. Strata that occur farther north are missing at these boundaries. The lower part of the Woodbine is missing at the Buda-Pepper boundary, and lower part of the Eagle Ford is missing at the Pepper-Cloice boundary.

Environments of deposition - The environment of deposition of the Pepper Shale is very peculiar. There is no silt, and all of the mollusks are extremely thin-shelled (paper thin) and appear to be mud burrowers. There are no foraminiferans except a few agglutinates. This has led to the interpretation that the Pepper Shale represents deposition in a lagoon near a carbonate terrain with brackish water and no terrigenous source of sediment.

Localities - The only locality at which the Pepper Shale can be readily observed in Austin is in the drainage ditch at the east side of the Missouri Pacific Railroad track on Barton Springs Road (Fig. 19).

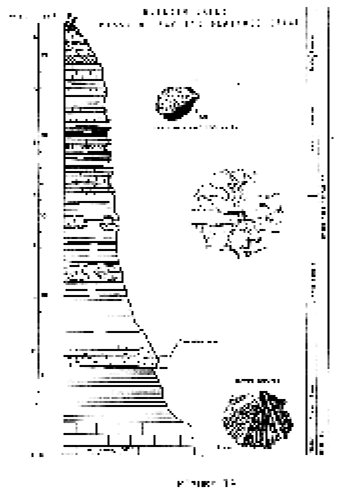

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Figure 19
Bouldin Creek - Missouri Pacific drainage canal

Cloice Shale Member

Localities - The Cloice is a dark gray shale that can be distinguished from the Pepper Shale because the Pepper Shale has an unctuous or soapy feel whereas the Cloice Shale is gritty to the touch. A hard, iron-containing layer separates the two. The Cloice Member is about 3.5 meters (11 feet) thick.

Boundaries - The lower boundary is disconformable with Pepper Shale, whereas the upper boundary is gradational with the overlying Bouldin Flags.

Environments of deposition - The Cloice Shale contains a foraminiferal fauna that is restricted, but seems to represent normal salinity; the member may represent lagoonal deposition with more of a terrigenous source than the underlying Pepper Shale.

Localities - Because it weathers easily the Cloice Shale does not occur in good outcrops. The best localities to see it are in the drainage ditch just east of the Missouri Pacific railroad track along Barton Springs Road (Fig. 19) and in the north bank of Bear Creek below the crossing of the old Manchaca-Buda Road.

Bouldin Flags Member

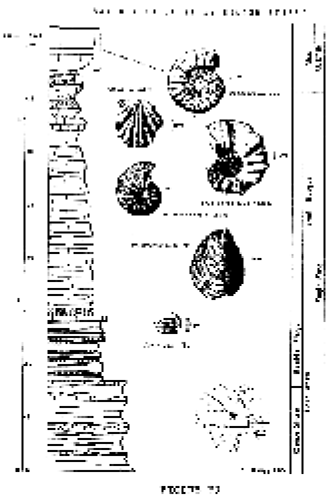
Localities - The Bouldin Flags Member consists of 5 meters (15 feet) of flaggy limestone beds (biomicrite or biosparite), each about 10 to 20 centimeters thick, separated by interbeds of shale similar to that of the Cloice Member.

Boundaries - The lower boundary of the Bouldin Flags Member is gradational to the Cloice Shale and the upper boundary is gradational to the South Bosque Member.

Environments of deposition - The flaggy limestone beds of the Bouldin Member contains bivalves (Inoceramus sp.) in conjunction with large sections of tree trunks (10 to 20 cms in diameter and up to 2 meters long), associated with shales containing a restricted foraminiferal fauna that seems to be of normal salinity. Silver (1963) has interpreted a similar deposit, represented by the Bluebonnet Flaggy Member farther north, as lagoonal.

Localities - The best places to visit the Bouldin Flags in the Austin area are in the drainage canal on the east side of the Missouri Pacific railroad track on Barton

Springs Road (Fig. 19), along Bear Creek below the crossing of the old Manchaca-Buda road, and on West Bouldin Creek just below Milton Street (Fig. 20).


(BIGGER)
Figure 20
Bouldin Creek at Milton Street

South Bosque Member
Localities - The South Bosque Member is a calcareous shale composed mostly of calcite and the clay mineral montmorillonite. The thickness of the South Bosque is about 5 meters (16 feet).

Boundaries - The lower boundary of the South Bosque is gradational with the underlying Bouldin Flags, but the upper boundary is disconformable with the overlying Austin Formation. At some places in Austin the top of the South Bosque is a "condensed zone". This is a zone of internal molds of many fossils that seems to represent 150 to 200 feet of section in Tarrant County that is characterized by discrete zones of fossils (Adkins and Lozo, 1951).

Environments of deposition - The South Bosque Member, with is wide variety of mollusks and foraminiferans, seems to represent marine, open shelf deposition.

Localities - The South Bosque is a soft rock unit, and because it weathers easily, outcrops are few. It can be observed best along Bouldin Creek just downstream from and around Milton Street in South Austin. The top of the member can be seen in the bank of Shoal Creek at Northwest Park in North Austin, and along Walnut Creek in the vicinity of Watters Park (Fig. 18).

AUSTIN CHALK

The Austin Chalk crops out in a wide belt almost through the center of the City of Austin, extending from south of Onion Creek all the way past Pflugerville. Interstate Highway 35 is constructed on the high ground that represents the Austin Chalk escarpment. Especially north of Austin it is possible to look down upon the formations near the Balcones Escarpment to the west, and also look down on the formations of the softer Upper Cretaceous shales to the east. The Austin Chalk is composed of several members: from bottom to top, the Atco, Vinson, Jonah, Dessau, Burditt, and Pflugerville Members. In addition, in the Pilot Knob vicinity, there are members made up of pyroclastic rock

("Pyroclastic Member") and beach rock (McKown Member). Some of these have been intruded by igneous rock.

Atco Member
The Atco Member has not been officially described previously, although it has appeared in the literature since Murray (1961). The original work on the stratigraphy (unpublished) was by C. 0. Durham and Kenneth 0. Seewald. The latter is credited here with measuring the type section (Fig. 21).

Type locality - The type locality of the Atco Formation is at the west quarry of the Universal Atlas Cement Company, Atco, McLennan County, Texas, about 8 miles southwest of the City Square of Waco (Fig. 21). Only the lower part of the formation is exposed at the type locality, but there is no better type locality, for no other locality exposes as well such a great thickness of the formation as does this one.

Type description - At the type locality the Atco Formation consists of the following sequence of beds (from K. 0. Seewald, unpublished) (Fig. 21).

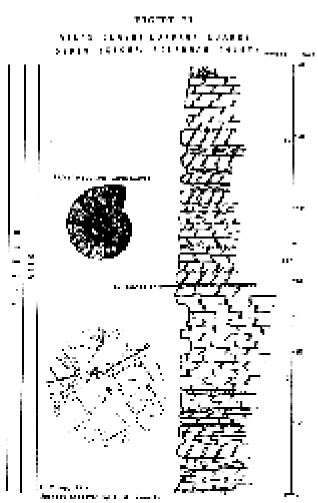

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Figure 21
Atlas Cement Company Quarry, South Bosque, McLennan County

Bed No.	Description	Thickness in meters	in feet
12	marl, chalky, weathered to a yellowish color	0.6	1.8
11	chalk, very hard, white, massive, a projecting ledge	0.5	1.5
10	chalk, marly, bluish-white, moderately resistant	1.8	5.4
9	marl, chalky, darker gray than above with thin shale stringer at top	0.6	1.7
8	alternating beds of chalk and chalky marl, light gray, moderately resistant	2.7	8.3
7	chalk, light gray, with thin shale stringer at top	1.3	3.8
6	bentonite	0.5	1.5
5	chalk, marly, moderately resistant	0.8	2.3
4	chalk, moderately resistant with thin shale stringer at top	1.0	3.8
3	chalk, marly, with thin shale stringer at top	0.9	2.8
2	chalk, marly, with thin shale stringer at top	1.0	3.1
1	chalk, moderately resistant with three thin shale stringers	3.2	9.5
	TOTAL	14.9	45.0

Localities - in the Austin area the Atco Formation consists of approximately 40 meters (120 feet) of alternating beds of chalky limestone, marly chalk, and thin shale stringers (all biomicrites with varying amounts of clay, but the clay content never exceeds 7 or 8 percent). At the type locality a key bentonite bed occurs 22 feet up in the section, and one mile north of Bruceville this bed is 29 feet above the base of the Austin Formation. At Watters Park in the Austin area there is a thick, hard, very light gray limestone at the base. This bed is from 3.3 to 5 meters (10 to 15 feet) thick.

Boundaries - The base of the Atco Member is unconformable as described under Eagle Ford Formation; the top is gradational with the Vinson.

Environments of deposition - The Atco Member represents deposition on an open, shallow shelf, far from the shoreline. The shallowness of the water is testified by numerous oysters, benthonic foraminferans, and inocerami.

Localities - In the Austin area the Atco Member can best be observed along Shoal Creek above Northwest Park, along west Bouldin Creek above Milton Street, along Walnut Creek above the North Lamar Bridge, on west Bouldin Creek at Oltorf Street, and along the Missouri Pacific railroad cut just north of Oltorf Street.

Vinson Member

The Vinson Member has not been described in the literature, although it has been used since Murray (1961). The original stratigraphy was done by C. 0. Durham and Kenneth 0. Seewald, but remains largely unpublished.

Type locality - The type locality of the Vinson is on Vinson Creek, about 0.8 kilometer (one-half mile) from Onion Creek on the Bluff Springs Road toward Interstate 35 from Bluff Springs, southeast of Austin, Travis County, Texas. The formation was named by Durham (manuscript) for Vinson Creek.

Type Section - Only the upper 15.5 meters (46.5 feet) of the approximately 27 meters (80 feet) of the Vinson Member are exposed at the type locality (Fig. 22). The lower part of the Vinson is exposed just west of Interstate 35 along Harper Creek, just south of the Colorado River, Austin, Texas. A complete section of the Vinson Member is not known. The type section (Fig. 22) follows:

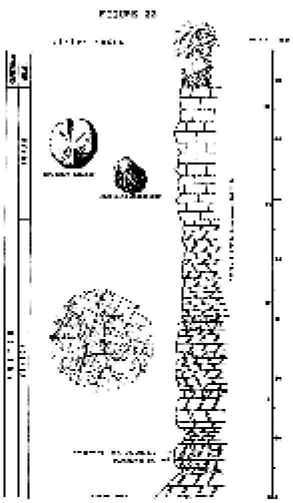

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Figure 22
Vinson Creek

Bed No.	Description	Thickness in meters	in feet
Jonah Member			
15	limestone, hard (biosparite)		

Vinson Member			
14	limestone (micrite), chalky with shaly layers	3.1	9.5
13	limestone (micrite), chalky with shaly layers	2.9	8.0
12	limestone (micrite), shaly and chalky	0.2	0.5
11	limestone (micrite), chalky	0.2	0.5
10	limestone (micrite), shaly and chalky	0.4	1.0
9	limestone (micrite), chalky	1.3	4.0
8	limestone (micrite), shaly and chalky	0.3	0.8
7	limestone (micrite), shaly and chalky	1.4	4.2
6	limestone (micrite), shaly and chalky	0.5	1.5
5	limestone (micrite), hard and chalky	1.6	4.5
4	limestone (micrite), shaly	0.8	2.5
3	limestone (biomicrite), hard and chalky with *Ehynchostreon* ? sp. aff. *subotbiculata* (Damarck) and *Pychodonte*- sp.).	1.3	3.9
2	limestone (biomicrite), hard and chalky	0.2	0.5
1	limestone (micrite), hard and chalky base at water level in Vinson Creek	1.3	3.7
	TOTAL	15.5	46.5

Localities - The lithology of the Vinson Member varies from limestone to chalky limestone to chalk, and a few thin beds may contain a small amount of clay and thus be shaly. Sometimes the section is almost entirely soft chalk; in other areas the section may be harder chalk with a conchoidal fracture. Storm beds with ripped up limestone fragments and shingled *Inoceramus* fragments are abundant. The Vinson differs from he Atco in having thinner shale beds and greater amounts of chalk.

Boundaries - The Vinson Member is conformable with the Atco M ember below and the Jonah Member above.

Environments of deposition - The Vinson Member represents environments on a broad, shallow, open, marine shelf well removed from the shoreline. The shallow water deposition, probably less than 30 meters, is attested to by many oysters and inocerami.

Localities - Waller Creek, in Austin, Texas, flows over Vinson from about 47th Street all the way to the Colorado River. The hard chalk with a conchoidal fracture can be observed on the grounds of the Hancock Golf Course. Storm beds of isolated or shingled fragments of Inoceramus shells can be observed at many places along Waller Creek. The Rhynchostreon ? sp. aff. suborbiculata (Damarck) beds and Pychondonte sp. occur below 38th Street in Waller Creek and again about 7th Street. The chalky facies with a minute undescribed species of Lopha are best observed at the south bank of the valley of Onion Creek about 200 yards east of Interstate Highway 35. Here also can be seen remarkable gullying controlled by jointing.

Jonah Member
The Jonah Member has not been properly described, although the name has appeared sporadically in the literature since Murray (1961).

Type locality - The type locality of the Jonah Member is on the left (Jonah) bank of the San Gabriel River at the crossing of the old road from Jonah to Hutto, Williamson County (Fig. 23). The member was studied, but not named by Marks (1950) and named by C. 0. Durham (unpublished) (Murray, 1961), and further studied by Kenneth 0. Seewald (unpublished).

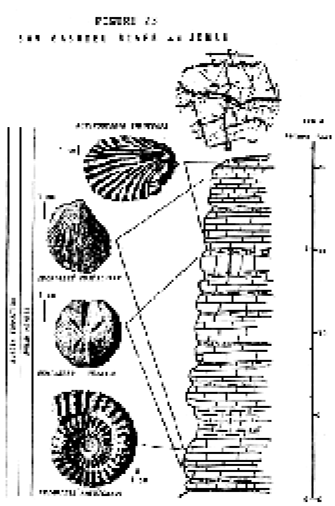
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Figure 23
San Gabriel River at Jonah

Type section - The type section described below is modified from Marks (1950, pp. 121-122 pl. 26):

Bed No.	Description	Thickness in meters	in feet

10	limestone (biosparite), gray, massive, undulating bedding, with Actinostreon travisana (Stephenson)	1.0	3.2
9	limestone (micrite), fissile, clayey, with Actinostreon travisana (Stephenson), and Pychodonte aucella (Romer)	0.1	0.4
8	limestone (biosparite), gray, undulating bedding, massive, with Actinostreon travisana (Stephenson)	0.7	2.0
7	limestone, shaly, with Hemiaster texanus (Romer) and Pychodonte aucella (Romer)	0.2	0.6
6	limestone, gray, with undulating bedding	0.3	0.8
5	limestone, shaly, with Hemiaster texanus (Romer) and Pychodonte aucella (Romer)	0.3	1.0
4	limestone, chalky, alternating with thin shaly beds	2.2	6.8
3	limestone (micrite), shaly, gray, fissile, undulating beds	0.8	2.2
2	limestone (micrite), hard, gray, (sparite cement scattered)	0.7	2.0
1	limestone (micrite) alternating with shaly limestone	0.5	1.4
	TOTAL	6.8	20.4

Base of section, but not base of formation.

Localities - The Jonah Member in the type area is recognizable because of the thick biosparites at the base and the top. It is less chalky than the underlying Vinson and the overlying Dessau Members. It can be mapped by its more rubbly outcrop and the larger clasts within its rock fragments. In other words, the Vinson and Dessau are largely mudstones, whereas the Jonah is large wackestones, packstones and grainstones; allochems are usually fossil fragments.

Boundaries - The lower boundary of the Jonah is conformable with the Vinson Member. The upper boundary of the Jonah is a bored and glauconitic corrosion zone that is recognizable over 40 or 50 miles of the outcrop. It marks the base of the upper chalk of older literature.

Environments of deposition - Both the Vinson and Dessau members are relatively free of burrowing mollusks, and the large specimens of Inoceramus, a bivalve, may indicate that the substrate was so soupy that burrowing mollusks could not obtain traction for the foot. This is not true of the Jonah Member. Burrowing mollusks, such as Idonearca Sp., abound, and the presence of Actinostreon, H m aster, and Spondylus guadalupae (Romer) attest to a shallow, open, marine shelf well removed from shore.

Localities - In the Austin area the Jonah is around 8.3 meters (25 feet) thick, thickening even more towards the type locality. To the south this coarser member is less prominent and more difficult to map. The Jonah can be seen in the Austin area just above the fault on Onion Creek upstream from Bob's Store in the Bluff Springs area, just south of Little Texas (Goodnight Lane) on South Congress, just below the bridge on the Hutto Road at Pflugerville, Travis County, and above the Vinson on Vinson Creek (Fig. 22).

Dessau Member

Localities - The Dessau Member ranges from 15 to 25 meters (45-75 feet) thick in the Austin area and consists primarily of chalk and chalky limestone. In north Austin a storm bed at the base has been termed the Schwertner bed, but it pinches out south of the Colorado River. In the middle of the Dessau Member is the Pychodonte aucella lumachelle (shell-bed). It ranges from 2 to meters (6 to 12 feet) in thickness and is composed of the stacked shells of this small relative of ancient oysters.

Boundaries - The lower boundary of the Dessau Member is locally disconformable with the Burditt Member. This local disconformity at the top of the Dessau can be associated with uplift in the vicinity of an ancient volcano in the Austin area now called Pilot Knob. The Dessau Member thins toward this ancient volcano, which raised the sea floor, resulting in less deposition and finally erosion in its vicinity.

Environments of deposition - The Dessau Member was deposited on a broad, open marine shelf far removed from the shore, as attested by the many oysters and inocerami.

Localities - The Dessau Formation is best exposed on Brushy Creek just below the old iron bridge on the Hutto- Manda Road. Nearer Austin it can be observed at the old Sprinkle Bridge over Little Walnut Creek (Fig. 24), below Dessau Road on Walnut Creek and its tributaries (Fig. 25), and on Rinard Creek at the old Turnersville Road crossing just east of Bluff Springs (Fig. 26), where it is much thinner than at the other mentioned localities.

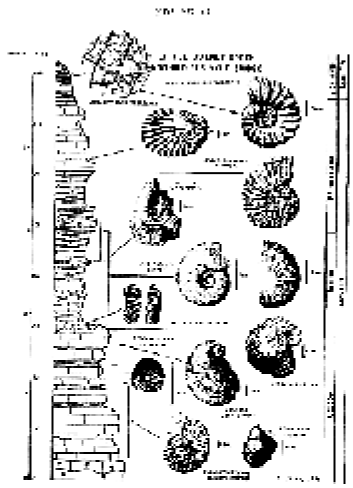 (BIGGER)

Figure 24
Little Walnut Creek and Old Sprinkle Bridge

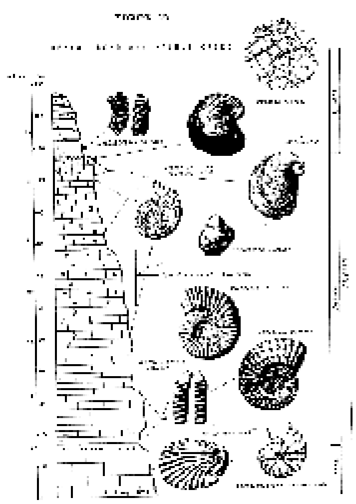 (BIGGER)

Figure 25
Dessau Road off Walnut Creek

Burditt Member

Localities - The Burditt Member is a soft, slightly clayey limestone (biomicrite) that weathers to a soft marly slope. It is about 5 meters (15 feet) thick in north Austin and thins to zero in the vicinity of Pilot Knob on onion Creek. The clay content never exceeds about 15 percent, and the base of the formation typically contains small, green, reworked fragments of the pyroclastic formation.

Boundaries - The lower boundary of the Burditt Member is locally disconformable; the upper boundary is gradational to the Pflugerville Member.

Environments of deposition - The environment of deposition is an open, shallow (as attested to by the many oysters) marine shelf well removed from the shoreline.

Localities - The Burditt Member weathers to a slope and is not easier observed. The best locality in the Austin area is just upstream from the Elgin Highway (Highway 291) on Little Walnut Creek. The formation can be observed from there all the way up Little Walnut Creek to a locality where it is faulted out just beyond the old Cameron Road crossing, now known only from the old bridge supports. This is its type locality (Adkins, 1933).

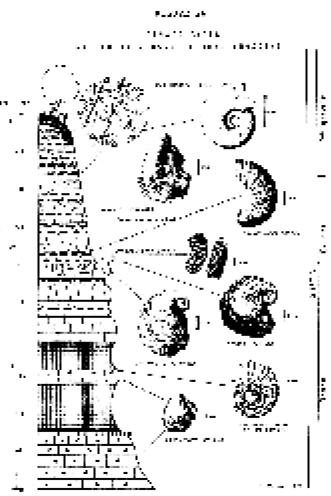 (BIGGER)

Figure 26
Rinard Creek at Old Turnersville Road Crossing

"Pyroclastic" Member

Localities - The pyroclastic rocks associated with the Dessau, Burditt, and McKown Members do not have formal nomenclatural status. They consist primarily of green clay (an iron-bearing montmorillonite similar to nontronite) and intertongue with the Dessau and the Burditt Members, occurring in the stratigraphic position of part of the Dessau and all of the Burditt at some localities (Fig. 26). They represent ash falls from various explosive craters that erupted during the deposition of the upper part of the Austin Chalk about 79 million years ago.

Boundaries - The boundaries of the pyroclastic formation are conformable with the overlying beds except along Onion Creek in the vicinity of Pilot Knob, where mud flows have been truncated by erosion before the deposition of younger Pflugerville and McKown members. Off Stasney Lane on Williamson Creek the pyroclastic formation truncates Vinson Member where the Vinson has been blown out of the crater prior to the deposition of the ejecta.

Environments of deposition - The pyroclastic rocks were deposited by ash falls from explosions of volcanoes; the ash fell into marine water and settled to the bottom to become clay. Later some of these clay beds were reworked by currents and waves to produce beach rock composed of fragments of claystone. Earthquakes accompanying the volcanism caused muds to flow down the sides of the volcano, producing mud flows that not only involve the pyroclastic rocks, but also involve the upper part of the Dessau Member (Fig. 27).

Localities - Explosion craters are known at Pilot Knob, under the bed of the Colorado River near Huston-Tillotson College, under St. Edwards University, at the intersection of West Bouldin Creek and Ben White Boulevard, along Williamson Creek just off of Stasney Lane, and in the Castlegate subdivision of South Austin - 6 separate explosion craters in all are known, each producing a certain amount of pyroclastic rock, but none as much as Pilot Knob. The best localities to observe pyroclastic rock are at the Lower McKinney Falls in McKinney Falls State Park (Fig. 27), in the valley between Elroy Road and Pilot Knob, downstream from the old Turnersville Crossing of Rinard Creek (Fig. 26), along Onion Creek below Bluff Springs, and along the rim rock north of Pilot Knob on Elroy Road south of Highway 183 (Fig. 28).

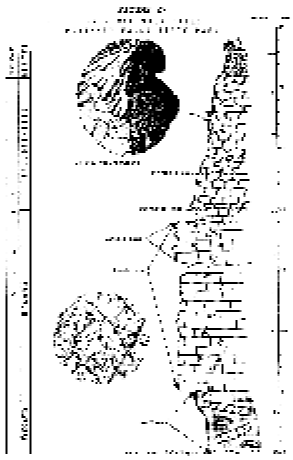

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Figure 27
Lower McKinney Falls, McKinney Falls State Park

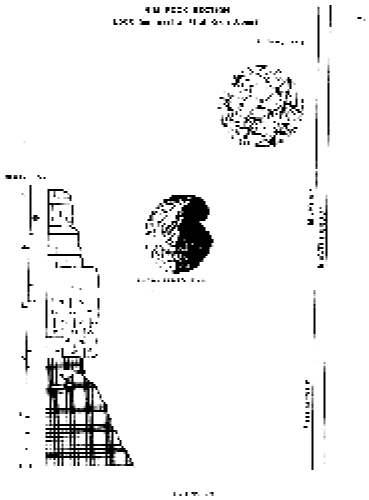

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Figure 28
Rim Rock Section (2500 feet west of Pilot Knob School)

"Basalt"

"Basalt" has been reported at four localities in the greater Austin area: (1) in the vicinity of Pilot Knob, (2) off Riverside Drive near Travis Heights, (3) in the subsurface by coring for foundation design at St. Edwards University, and (4) on Boggy Creek north of 7th Street (Hill and Vaughan, 1901; Moon, 1942). The Riverside Drive and Boggy Creek localities have since been covered by fill for development.

Localities - Although commonly called "basalt", the igneous rock in the Austin area is not true basalt, but consists of two rock types, nepheline basanite and olivine nephelinite.

Boundaries - There are two types of boundaries, usually not observable. Some of,the igneous rock is intrusive, cutting the rocks, and some of it has flowed out over the ground surface to be covered by later marine deposits (McKown or Sprinkle).

Localities - Igneous rock in place is not easy to see. The south end of Pilot Knob is the best exposure of igneous rock in place, and at South Pilot Knob on Bluff Springs Road igneous rock can be seen that has not moved more than two or three feet since it solidified.

Pflugerville Member

The Pflugerville Member has not previously been described. This is probably the Big House Formation mentioned by Murray (1961), but since that formation has never been described and is not now used in the type area, Pflugerville will be described in the Austin area. C. 0. Durham and Kenneth 0. Seewald have both studied the formation, but most of their work remains unpublished.

Type locality - The Pflugerville Member is named for the village of Pflugerville north of Austin, Travis County, where the formation underlies the Immanuel Lutheran Church. The type locality is selected at the curve in Cameron Road on levels (presumably bedding planes) at which Exogyra erraticostata and Actinostreon travisana (Stephenson) are concentrated. These may have represented submarine hard grounds. On Little Walnut Creek, just upstream from the Manor Highway (Highway 291), there is a shell hash about 5 centimeters thick near the middle of the member (Fig. 29). In some parts of the Pilot Knob area the member thins to as little as 3 meters (10 feet), and in other areas it is entirely replaced by beach rock (McKown Member). On Jane's Farm at Onion Creek the Pflugerville Member discordantly overlies pyroclastic and Dessau mud flows (Fig. 30).

Boundaries - The lower boundary of the Pflugerville Member is gradational with the Burditt Member below, and the upper boundary is gradational with the overlying Sprinkle Claystone. The upper boundary may have a concentration of internal molds of Idonearca sp. in living position (Fig.31).

Environments of deposition - Beds of the Pflugerville Member represent a broad, shallow, open marine shelf. The numerous oysters testify to the shallow deposition, which probably took place in less than 30 meters of water. This member contains one of the finest and most beautiful foraminiferal faunas in the Cretaceous of Texas.

Localities - The Pflugerville Member weathers rapidly. It can be easily observed at the type locality along the curve on Cameron Road on the south side of Walnut Creek (Fig. 32). Until developers destroy the outcrop the Pflugerville can also be easily seen on the slopes of Little Walnut creek above the stained waterfall about 200 meters upstream from Manor Highway Bridge (Highway 291) (Fig. 29), just north of Reagan High School. The base is exposed at the old Turnersville Road crossing of Rinard Creek (Fig. 26).

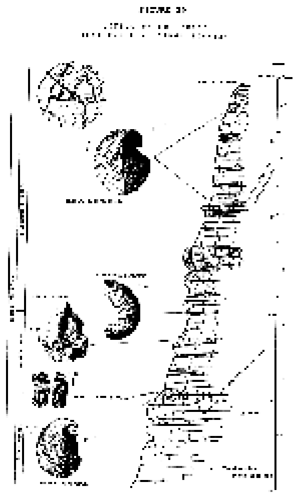
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Figure 29
Little Walnut Creek just north of Manor Highway

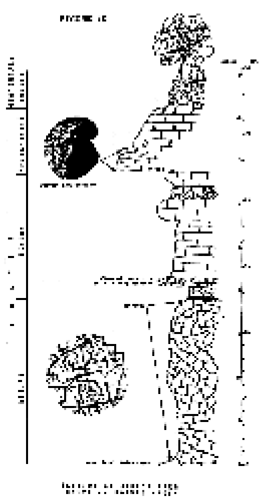
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Figure 30
Section at Jane's Farm, Mouth of Marble Creek

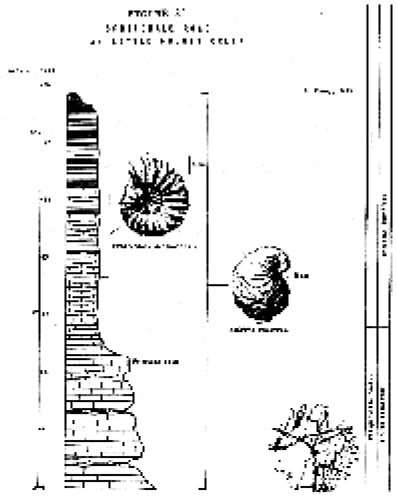 (BIGGER)

Figure 31
Springdale Road at Little Walnut Creek

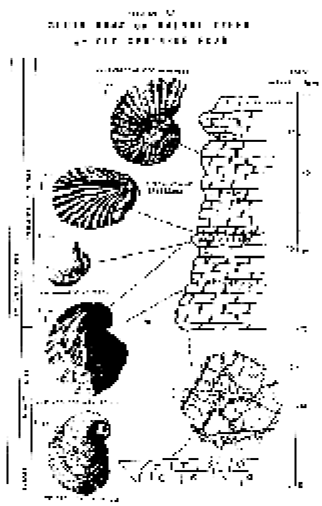 (BIGGER)

Figure 32
South Bank of Walnut Creek at Old Sprinkle Road

McKown Member

The McKown Member is described herein and refers to the hard beach rock facies of the Pflugerville and perhaps the upper part of the Dessau near Pilot Knob.

Type locality - The McKown Member type locality is the McKown Quarry on the north side of Onion Creek approximately 1.6kilometers (I mile) above the Lockhart Highway (Highway 183)(Fig. 33).

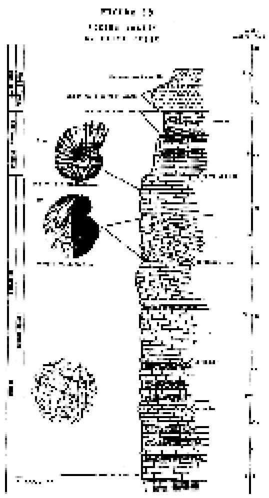 (BIGGER)

Figure 33
KcKown Quarry on Onion Creek

Type section - The type locality exposes a complete section of the McKown Member, a total of about 18 meters (55.5 feet).

26 Houston soil profile 1.0 3.0 Onion Creek Terrace

Bed No.	Description	Thickness in meters	in feet
	Soil		
	Quaternary		
25	gravel, golf ball size and larger chert and limestone pebbles	1.6	4.7
	Sprinkle Formation		
24	caliche (weathered profile on montmorillonitic clay)	1.5	4.5
23	clay, dark gray, montmorillonitic	2.5	7.6
	McKown Member		
22	limestone, shell beach, (biosparite or shell frag- ment grainstone), nodular bedding, corrosion zone at top	2.5	7.6
21	limestone, same as bed 22, but evenly bedded	1.2	3.8
20	limestone, same. as bed 22	1.2	3.9

19	limestone, same as bed 22, but with Exogyra errati-costata (Stephenson) through-out and corrosion zone at top	2.1	6.3
18	limestone, same as bed 22, but rubbly and burrowed at top with corrosion zone	0.5	1.6
17	conglomerate of reworked and water-worn fragments of the pyroclastic member	0.1	0.4
16	limestone, same as bed 22, but evenly bedded	1.4	4.4
15	limestone, same as bed 22, but evenly bedded	1.4	4.2
14	limestone, same as bed 22	0.5	1.6
13	limestone, (biosparite) with large (4 to 10 centi-meters) horizontal, (1 to 2 centimeters thick) fine grained limestone (micrite) clasts and with pronounced stylolite at top	0.4	1.2
12	limestone, same as bed 22	0.7	2.1
11	limestone, same as bed 13	0.4	1.4
10	limestone, same as bed 22	0.4	1.2
9	limestone, same as bed 13	0.4	1.2
8	limestone, same as bed 22	0.4	1.2
7	limestone, same as bed 22, and with pronounced styolite at top	1.1	3.2
6	limestone, same as bed 13	0.4	1.2
5	limestone, same as bed 22	0.5	1.6
4	limestone, same as bed 13	0.3	1.0
3	limestone, same as bed 22	0.5	1.6
2	limestone, same as bed 13	0.4	1.2
1	limestone, same as bed 22	1.2	3.6

Pyroclastic" Member			
0	green, reworked ,pebbles of clay		
	TOTAL THICKNESS OF McKOWN:	18.0	55.7

Localities - The lithology of the McKown Member is primarily a calcarenitic limestone (oyster shell biosparite or oyster shell grainstone). It is clean with little micrite and no clay. The micrite clasts in bed 13 and similar beds are about the only exception. Fragments of reworked Pyroclastic Member are not uncommon at some levels.

Boundaries - At some localities the lower boundary is gradational with the Dessau Member. At other localities the lower boundary is gradational with the pyroclastic member. But along Onion Creek at several localities, especially on Jane's Farm and McKinney Falls State Park the McKown Formation rests discordantly on the mudflows of the Dessau and "Pyroclastic" Member. Just above the Highway 183 bridge across Onion Creek the McKown rests with sharp disconformity on the Dessau.

Environments of deposition - The McKown Member represents the beach facies of the old volcano of Pilot Knob. At some localities it grades laterally into "Pyroclastic" Member beach facies. The beach environment was most greatly developed on the north and east side of the old volcano; beach facies of other old igneous plugs in the area, such as those at Thrall and Kimbro, are best developed on sides ranging from northwest to southeast. Just upstream from the Highway 183 bridge on Onion Creek the McKown has a number of beds that contain algal fragments intercalated among strata of the beach rock (White, 1960).

Localities - The best localities to visit the McKown Formation are along Onion Creek on the grounds of McKinney Falls State Park. The two falls (Upper and Lower McKinney Falls) are held up by the McKown Formation, and just above the Lower Falls an old beach berm has been preserved and re-exhumed. The many quarries on Onion Creek below McKinney State Park, which have been utilized by the Texas State Highway Department for many years, are in the McKown Formation (Fig. 33). This limestone is easily crushable, but then case hardens to produce a good aggregate. The J. K. Ross, old McKinney, and other early ranch buildings along this part of Onion Creek are and were constructed from stone of the McKown Member. Some of the stone was hand chiseled, but stone in other buildings has been sawed. McKown is also exposed on the Jane's Farm (Fig. 30) and in the Rim Rock section on Elroy Road (Fig. 28).

SPRINKLE FORMATION

In the Austin area the Sprinkle Formation (often referred to as the Lower Taylor Clay) is exposed in valleys and gullies under gravel around the south, east and north sides of the Municipal Airport, and extends up Little Walnut Creek to Springdale Road. There is a graben of Sprinkle along Little Walnut Creek 0.8 kilometers (one-half mile) below the Manor Highway (Highway 291) Bridge. Walnut Creek Sprinkle is exposed downstream and northeast of Sprinkle, but only on the south side of Walnut Hill. The Sprinkle is one of the most unstable formations in the Austin area; it has caused many construction failures, and construction upon this formation should be done only under the watchful eye of an engineer or geological engineer.

Localities - The Sprinkle Formation is a calcareous claystone. The primary clay mineral is montmorillonite with sodium dominant over calcium. The calcium carbonate ranges from around 10 percent to over 40 percent. The Sprinkle is about 100 meters (300 plus feet) thick, but varies, being thinner on the tectonic highs coincident with and adjacent to igneous plugs.

Boundaries - The lower boundary of the Sprinkle is usually conformable with the Pflugerville Member of the Austin. At Little Walnut Creek below Springdale Road (Fig. 31) the boundary is marked by a sudden decrease in calcium content and a number of internal molds of Idonearca sp. (a burrowing clam) in living position. In the Pilot Knob vicinity the Sprinkle may be separated from members of the Austin Formation by a local disconformity associated with tectonic activity of the old volcano.

Environments of deposition - The Sprinkle Claystone represents deposition far offshore in a shallow marine environment. The fossil oysters and other pelecypods certainly indicate deposition in depths of less than 60 meters, and probably less than 30 meters. The source of the clay is not local and is most likely due to the slow outfall of volcanic dust produced by numerous volcanoes in the ancient mountains of the western United States at that time.

Localities - The best localities to see Sprinkle Claystone are fresh road cuts. The formation is so soft and weathers so rapidly that there are few old classic localities. Therefore, it is necessary to watch for fresh exposures. The base of the Sprinkle is usually observable on Little Walnut Creek about 35 meters (100 feet) downstream from the Springdale Road (Fig. 31).

PECAN GAP CHALK

The Pecan Gap Chalk is a chalky or marly formation between the Sprinkle Claystone below and the Bergstrom Claystone above. It is roughly 15 to 25 meters (50-75 feet) thick, depending on the variation in facies relationships with the overlying Bergstrom. The Pecan Gap crops out mostly east of Austin and does not appear south of Walnut Creek. It is faulted out on the Hornsby Bend Fault from north of Hornsby Bend to beyond Pilot Knob.

Localities - The Pecan Gap ranges from a marl to a chalk. In the Austin area it would mostly be called a marl, with calcium carbonate content ranging from around 25 to over 75 percent. At Cele in northeastern Travis County, and at Normann's Crossing of Brushy Creek, it is a true chalk. The chalky areas are usually associated with topographic highs on the Cretaceous sea floor, as that associated with the Kimbro structure in eastern Travis and adjacent Williamson Counties.

Boundaries - The lower boundary of the Pecan Gap Chalk is sharp on the Sprinkle, but is probably not disconformable. The upper boundary is slowly gradational into the Bergstrom Claystone and cannot usually be distinguished within plus or minus 10 feet.

Environments of deposition - The environment of deposition for the Pecan Gap Formation is offshore open shallow sea. The many species and specimens of the clam Inoceramus and the numerous oysters indicate depths of not more than @O meters and probably less than 30 meters. Carbonate deposition usually exceeded clay deposition.

Localities - Good outcrops of Pecan Gap are rare because the formation weathers so easily. Fresh cuts along the west side of Walnut Hill (Fig. 34) are usually good collecting sites. Outcrops of Pecan Gap Chalk can be seen at Cele in northeastern Travis County, and just upstream from Normann's Crossing of Brushy Creek.

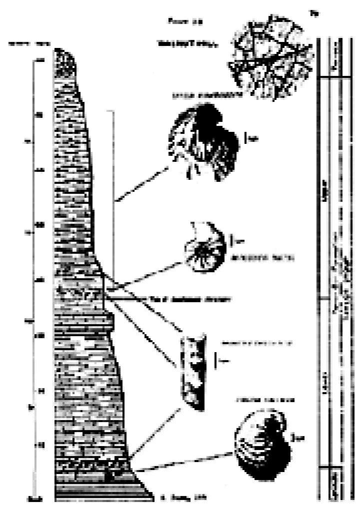
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Figure 34
Walnut Hill

BERGSTROM FORMATION

The Bergstrom Formation is best developed in the valley of Gilliland Creek around Manor and northeast down Wilbarger Creek. It also may be seen east of Onion Creek at Moore and Berry's Crossing. The Bergstrom, like the Sprinkle, is one of the more unstable formations in the Austin area.

Localities - The Bergstrom Formation is a montmorillonitic claystone. Calcareous content ranges up to 25 percent, but the latter figure is only at the base near the Pecan Gap Chalk. Higher in the formation the calcium carbonate percent is frequently less than six and may be as low as 3 or 4 percent. In the area around New Sweden, Manda, and Kimbro, the upper part of the Bergstrom is characterized by large irregularly shaped, sometimes septarian, sometimes calcite filled concretions. These may contain fossils. These concretion zones are apparently associated with a slightly higher sea floor. Total thickness of the Bergstrom ranges from 100 to 125 meters roughly 300 to 375 feet).

Boundaries - The boundaries of the Bergstrom Formation are seldom seen. The lower boundary is gradational with the Pecan Gap Chalk. The upper boundary is said to be disconformable, but this disconformity is not apparent (Fig. 35) (Young, 1965). The disconformity was once exposed at Noack (Fig. 35), but has since been covered by slump.

Environments of deposition - The Bergstrom Claystone represents deposition in an open, offshore, shallow seaway. The many large specimens of Exogyra ponderosa and occasional large rudistids testify to deposition in the neritic zone. The source of the montmorillonite is thought to be slow outfall of dust from numerous volcanoes then extant in the western United States.

Localities - Like the other clay formations, the Bergstrom weathers rapidly, and is best exposed in fresh cuts on newly constructed roads. There is a good outcrop in the west bank of Onion Creek about 100 meters upstream from the old Moore and Berry's Crossing; this was one of Helen Jeanne Plummer's favorite collecting sites for Foraminifera. Bergstrom Claystone can also be observed in the north bank of the Colorado River below the Hornsby Cemetery and at the ramp down to the Colorado River at Del Valle.

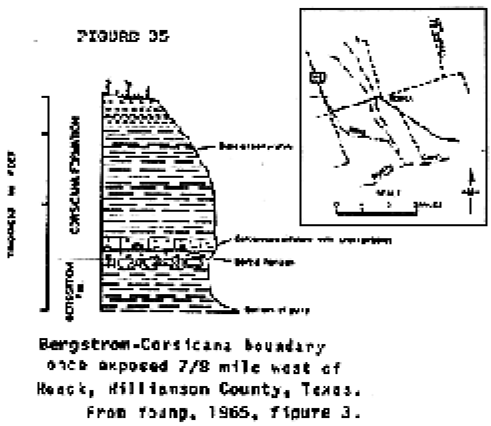

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Figure 35
Bergstrom-Corsicana boundary once exposed 7/8ths mile west of Noack, Williamson County. Texas
From Young, 1965, figure 3

CORSICANA FORMATION

The Corsicana Formation is another of the claystones that together with the Sprinkle, Pecan Gap, Bergstrom, Kemp, and Paleocene formations, make up the blacklands so valuable to farming in central and north Texas. The Corsicana crops out in the eastern and northeastern parts of the County. It is about 34 meters (110 feet) thick.

Localities - The Corsicana Formation is another montmorillonitic claystone with sodium dominant over calcium, and it is just as unstable as the Sprinkle and Bergstrom Formations. The Corsicana is calcareous at many levels, seemingly largely due to the presence of minute calcareous foraminiferans. The source of the clay is thought to be the outfall from the numerous late Cretaceous volcanoes in the western part of North America.

Boundaries - The boundaries of the Corsicana are seldom observed. The lower boundary can be observed at the top of the cliff just below the thin, platy siltstones below Jones' Crossing (Bastrop Highway). It is gradational with the Kemp Formation.

Environments of deposition - The environment of deposition of the Corsicana Formation should be the same as that for the Bergstrom Formation.

Localities The lower part of the Corsicana Formation can be observed in the south bank of Gilliland Creek just upstream from Texas Highway 973. The best exposure is at the large bluff just north (downstream on Onion Creek) of Jones' Crossing (Bastrop Highway bridge).

KEMP FORMATION

The Kemp Formation crops out in the eastern part of the County, and except for an area along the Bastrop Highway the other side of Onion Creek it will probably not be included even in the greater Austin area for some years. It is the youngest of the Cretaceous formations in Central Texas.

Like the other later Cretaceous formations the Kemp Formation is montmorillonitic claystone, but it contains at some levels the thin, flaggy, quartz siltstones that differentiate it from the Corsicana Formation. Since there are several feet of these siltstones at the base of the Kemp, there is a small basal scarp in eastern Travis County, and the formation can be mapped more easily than the Bergstrom.

Boundaries The lower boundary of the Kemp is gradational to the Corsican. The upper boundary is disconformable with the Paleocene Midway Formation. The latter boundary is usually burrowed; the burrows are filled with overlying Midway glauconites, and there are fragments of worn Cretaceous fossils for several feet into the overlying Midway Formation.

Environments of deposition - The Kemp Formation represents deposition in an open, offshore, shallow seaway, and the increasing amount of quartz silt indicates an additional source other than volcanic dust.

Localities - About the only place the Kemp Formation can be observed in the Austin area is where the lower part is exposed in the top of the bluff below Jones' Crossing (Bastrop Highway) on Onion Creek.

TERRACE DEPOSITS

Terrace deposits in the Austin area are Quaternary (Holocene and Pleistocene). They can be divided into (1) the upper deposits, which are gravely, red deposits such as those at the Municipal Airport surface and the Capitol grounds, and (2) the lower alluvial deposits, such as those along Boggy Creek, in the bank of Waller Creek at the 1st Street Bridge, or the recent deposits of the Colorado River alluvium.

Localities - The higher terrace deposits are coarse-grained, gravelly, reddish deposits. The lower deposits may also be red, but they are a finer-grained, usually sandstones and sandy siltstones.

Boundaries - Terrace deposits rest disconformably upon older deposits.

Environments of deposition - The terrace deposits are all alluvial, representing various fluvial regimes including channel, overbank, point bar, chute, and natural levee. The deposits represent former levels of the Colorado River and its tributaries. Terrace deposits of tributary streams contain rock particles similar to the country rock in their vicinity.

Localities - Terrace deposits can be observed at many localities. Higher gravels are best observed along Ed Bluestein Boulevard opposite Tracor. Lower deposits can be observed wherever a tributary channel cuts through the floodplain, as off Bolm Road, along Boggy Creek, and near the Colorado River at Waller and Shoal Creeks.

Chapter 3: The Balcones Fault Zone of Austin

M. A. Jordan

THE BALCONES ESCARPMENT

Introduction

Driving on Interstate Highway 35 between Austin and San Antonio, one observes that the land to the east is for the most part relatively flat, whereas the land to the west is more rugged and higher, Austin, San Marcos, San Antonio and other towns along this part of the Interstate Highway 35 are all located at or near this obvious change in topography, which commonly is called an escarpment. Generally speaking, an escarpment is the relatively steep face that separates two regions of markedly different elevation. Along most of the Balcones Escarpment, the land to the west averages about 300 feet higher than the land to the east.

FORMATION OF ESCARPMENTS

Most escarpments, including the Balcones, are the result of differential erosion, which occurs when there are variations in the ability of exposed rock to resist erosion. The old saying "the rain falls alike on the just and the unjust" can be applied to resistant and non-resistant rocks. Erosional agents, such as rain, attack with essentially equal vigor all over the land along the Balcones Escarpment. But the rocks on the west side are more resistant to erosion, and have been worn down less than the rocks on the east side, with the passage of time and countless rainstorms. So, "differential erosion" describes the result of erosional processes acting on rocks with different properties -- properties which influence the rocks' susceptibility to erosion. **Figure 36** is a profile of a hypothetical escarpment, showing locations of resistant and non-resistant rocks.

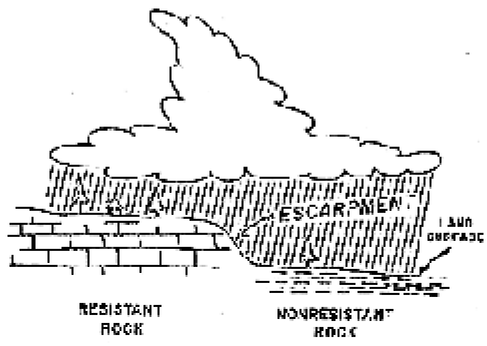

FIGURE 36
Profile of an Erosional Escarpment

(BIGGER)

Figure 36

The face of the escarpment usually looks more scarred by erosion than any other part of the area, because erosive power of water is greater on the steep slope of the face. Gullies and canyons occupied by fast-flowing streams may extend into the high-country side, but the streams normally become more serene as they flow into the low country. The face of an escarpment may be the site of waterfalls if it is a "young" escarpment, or if the contrast in resistance to erosion of the rocks is especially great. The Colorado River exhibits some of these features as it flows across the Balcones Escarpment and through Austin. In the hill country west of town the river flows through a relatively deep, steep-walled valley which has been dammed to make Lake Austin, Lake Travis, and other lakes further upstream. However, for most of its path through Austin the Colorado River flows across a relatively flat surface. The change in the river occurs just as it flows past the Balcones Escarpment, the result of differences in the ability of rocks to resist erosion. Now we shall examine the reasons for the differences in the rocks.

ROCKS EXPOSED ALONG THE BALCONES ESCARPMENT

In the Austin area the rocks along the Balcones Escarpment have been assigned, according to their composition, to several units. The resistant rocks to the west belong mostly to either the **Glen Rose Limestone** or to the **Edwards Limestone**. Less resistant rocks dominate the area to the east. There one finds rocks of the Austin Group, made up mostly of several soft limestone formations. We will not bother with the names of the individual units of the Austin Group in this discussion, but it is worth noting that for many years, the entire unit has been known informally as the "Austin Chalk" (a thorough examination of the **Austin Chalk** is given in **Chapter 2**). Other units exposed east of the Balcones Escarpment include the **Del Rio Clay**, and the **Eagle Ford** and **Georgetown** Formations. All of these are relatively "soft" units. The **Buda Limestone**, a relatively resistant unit, is also found on the east side of the escarpment, but it is only about 40 feet thick and has a minor influence on the overall topography. For that matter, the non-resistant **Walnut Clay** occurs with the **Edwards Limestone** to the west, but is also too thin to have much influence on the topography. In summary, we have at the surface in the Austin area several different types of rock, each with different abilities to resist erosion relative to the other rock units. **Figure 37**briefly outlines the erosive properties and reviews what we know about thickness, lithology, sequence of deposition and relative ages of these units.

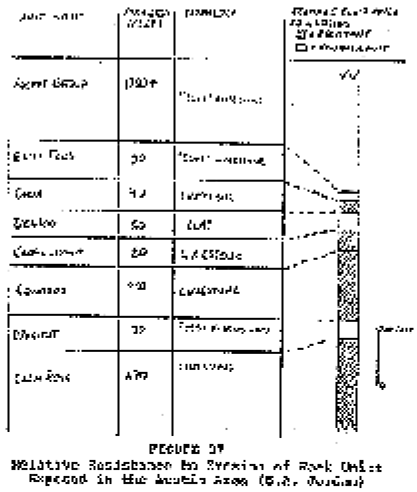

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Figure 37
Relative Resistance to Erosion of the Rock Units Exposed in the Austin Area (M.A. Jordan)

Knowing that the lower units (Glen Rose, Walnut, and Edwards) appear at the ground surface west of the escarpment, and that the upper units are exposed at the surface on the east, we see that the normal stratal sequence has been disrupted. In effect, the earth's crust has broken and the rocks have moved so that rocks of different age or position in the rock column are brought next to each other. This happened by faulting; faults are fractures along which movement occurs or has occurred. **Figure 38** shows an idealized fault and how rock units are displaced along it. The Balcones faulting resulted in upward movement of the rocks on the west side of the fault zone.

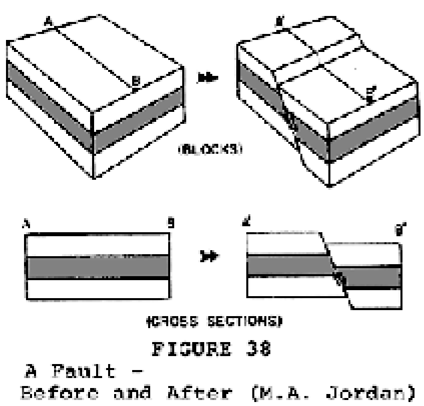

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Figure 38
A Fault - Before and After (M.A. Jordan)

Figure 38 also suggests that faults themselves can produce clifflike topography. In fact "fault scarps" can often be found associated with recent faults, but erosion usually attacks them vigorously and they disappear rapidly. Normally it takes only a few years or decades--"an instant" from a geologist's point of view--to remove or make practically unrecognizable such evidence of faulting. Much of the time erosion can wear down the rocks faster than faults can lift them up. Unless a contrast in resistance to erosion is produced, bringing a "hard" rock to a "soft" one at the surface, a fault scarp will not last long. In the Austin area, hundreds of feet of overlying rock have been removed by erosion since the time of Balcones faulting. The Balcones Escarpment of today is essentially a product of differential erosion, although it probably was expressed as a fault scarp at various times during the actual faulting.

Between the time of faulting and the present, as erosion progressed, there may have been times when there was no escarpment at all, or even times when the topography was reversed. After faulting ceased, the topography depended on which rock units were exposed to erosion. **Figure 39** shows how the topography near a fault might change through time. With so much erosion in the Austin area, it is coincidence that the topography along the Balcones Escarpment "agrees" with the fault movement.

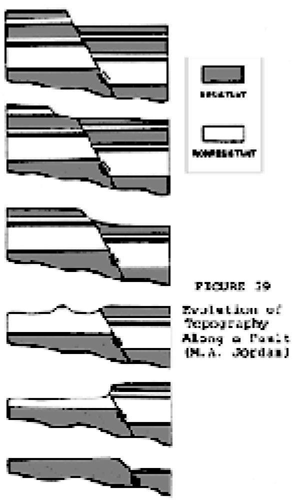

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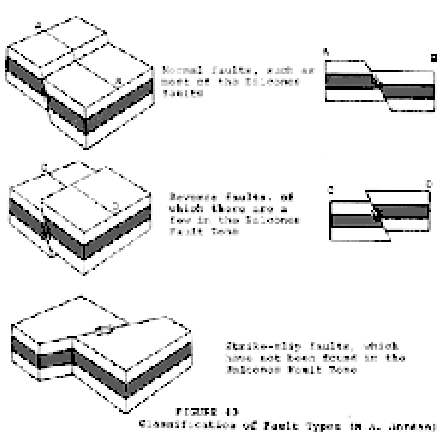
Figure 39
Evolution of Topography Along a Fault (M.A. Jordan)

MOVEMENT IN THE BALCONES FAULT ZONE

Based on the direction if the relative movement, faults are classified into several types. As shown in Figure 40, three basic categories are:



(BIGGER)

Figure 40
Classification of Fault Types (M.A. Jordan)

With normal faults, the movement is such that the fault plane dips, usually steeply, toward the side of the fault where the rocks have dropped. It is as though the rocks slid down the inclined fault surface, propelled by gravity. Reverse faults are so named because the movement they show is opposite to that of normal faults. With reverse faults, the rocks appear to have been pushed up the fault plane, against the force of gravity. In strike-slip faults the movement is horizontal, similar to the way in which two ships might grind together if they try to pass too closely by each other.

In the Balcones Fault Zone the movement was predominantly along a group of normal faults. The eastern side of the fault zone is the "downthrown side", or it is equally correct to say that the west side is "upthrown". In places along the fault zone where the rock exposures are good, we can measure the amount of movement that occurred. The maximum figure we get is a little over 700 feet. The few reverse faults in the Balcones Fault Zone are the result of minor localized "adjustments" during the faulting. The greatest known movement on a reverse fault in this area is only a few feet.

Balcones faulting occurred in the Miocene Epoch (27 to 12 million years ago), not too far back in geologic time. We can date the age of the faulting because of the presence, a few miles east of Austin, of Miocene-age conglomerates, containing clay, sand and pebbles derived from the initial fault scarp. It probably took several millions of years for all the fault movement to take place. We can be sure of this because, around the world, presently-active faults are not observed to move more than about 30 feet at a time. The movement episode may last only a few seconds--and usually results in an earthquake--but this is followed by a period of relative quiescence which may last for hundreds of years or more. During the quiescent period subterranean forces build up slowly to the level necessary for another episode of fault movement. Erosion acts at an accelerated pace on fault scarps, explaining the origin of the conglomerates by which Balcones faulting was dated. The scarp that existed during the faulting was probably never very high, however.

All the evidence indicates that Balcones faulting has ceased. The Balcones Fault Zone does not threaten us with earthquakes. In fact, no earthquakes have been recorded as originating from here since the instruments have been available with which we might observe them. Austin is located in an "aseismic zone" on the Seismic-Risk map of the United States, which means that there is little or no reason to expect damage from earthquakes.

The main problem associated with faults in the Austin area is that builders must be very careful in their appraisals of construction sites. Faults observed at the surface are a warning that the bedrock in an area may be inhomogeneous. Detailed study of a construction site with faults is needed, because construction plans may have to allow for the variations in the bedrock. If hard rocks turn up unexpectedly where the builder thought there were soft rocks, he may lose money because the cost estimate in his excavation contract was too low. On the other hand, unexpectedly soft rocks can increase foundation costs, because additional precautions against damage by settling will be necessary. The Leaning Tower of Pisa is a famous example of a building with a settling foundation: it is scenic, and a great tourist attraction, but nobody wants a leaning apartment building or a sunken office complex!

GEOLOGIC FRAMEWORK OF THE BALCONES FAULT ZONE

The Balcones Fault Zone actually consists of many individual faults. No single fault extends for the whole length of the fault zone. The amount of movement that can be measured on each individual fault varies, depending upon where along the trace of the fault measurements are made. Near the middle part of a fault's length is where we usually find the maximum movement. Going toward either end of the fault trace we typically observe that the amount of movement dwindles down to nothing, and the fault "dies out" into unbroken rocks. However, if we observe adjacent faults, we can see that the movement on them may increase as the movement on the other fault decreases, so that the amount of movement measured across the entire fault zone remains relatively constant. Only as we approach the ends of the entire fault zone do we find that the number of faults, and the total movement on them begins to decrease. **Figure 41** shows how two or more faults can share the total of movement across a fault zone, and how one fault can decrease in magnitude as an adjacent fault increases in magnitude. **Figure 42** shows the "dying out" of a neighborless fault. Such phenomena are common all along the Balcones Fault Zone. Faults can also split up or join together, as in **Figure 43**, producing what are commonly known as fault slivers, drag-blocks, or fault slices. **Figure 44** shows a drag-block formed by the splitting and rejoining of a fault. A good example of this in the Austin area will be described later.

The Balcones Fault Zone is part of a large fault system. Near the town of Luling, several miles south of Austin, is another fault zone trending roughly parallel to the Balcones Zone, called the Luling Fault Zone. The Luling Fault Zone is made up largely of normal faults which dip toward Austin, and the rocks are downthrown to the northwest. Thus the rocks between Luling and Austin are like a strip which has dropped downward between the two fault zones. This type of structure is called a graben, or a block downdropped between two normal-fault zones **(Fig. 45)**.

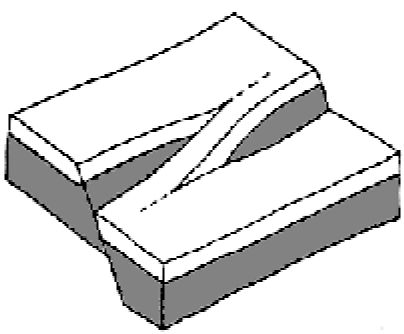


FIGURE 41
Sharing of Displacement of a Fault (M.A. Jordan) **(BIGGER)**

Figure 41
Sharing of Displacement of a Fault (M.A. Jordan)

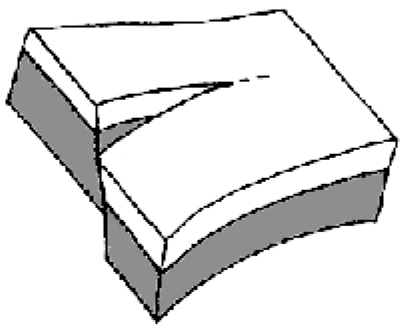


FIGURE 42
"Dying-out" of a
Fault (M.A. Jordan)

(BIGGER)

Figure 42
"Dying-out" of a Fault (M.A. Jordan)

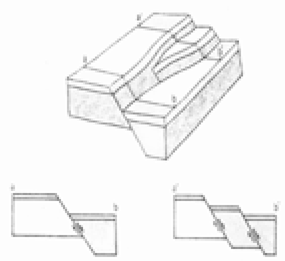


FIGURE 43
Joining (or Splitting) of a Fault (M.A. Jordan)

(BIGGER)

Figure 43
Joining (or Splitting) of a Fault (M.A. Jordan)

In turn, the Balcones-Luling Graben System is one of many grabens which have been discovered throughout the margin of the Gulf of Mexico. In most of these faults, the faults trend roughly parallel to the present shoreline of the Gulf. Several of the grabens nearer the Gulf have been partially or completely buried by sedimentation, and were recognized mainly in the course of drilling for oil, or other subsurface exploration.

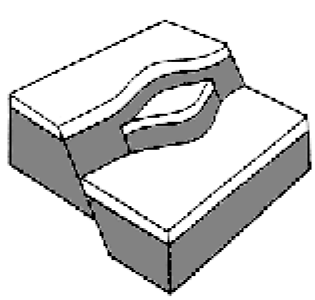


FIGURE 44

A Drag-block (M.A. Jordan)

(BIGGER)

Figure 44
A Drag-Block (M.A. Jordan)

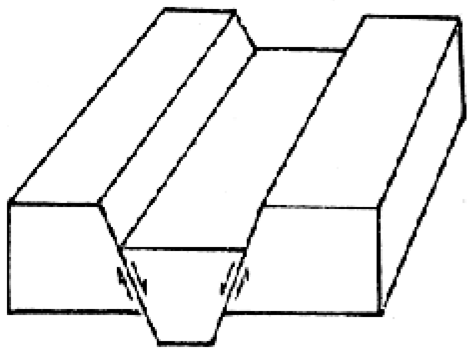


FIGURE 45
A Graben (M.A. Jordan)

(BIGGER)

Figure 45
A Graben (M.A. Jordan)

The Cretaceous rocks of the Austin area formed predominantly as deposits on the floor of shallow seas and associated lagoons. In effect, about 100 million years ago, the Gulf of Mexico covered a much greater area than it now does. Beneath these relatively young deposits lies an assemblage of several kinds of older rocks, some of which were formed as long ago as 1.2 billion years. As it turns out, Austin and much of the Balcones Fault Zone lie almost directly above a "seam" in the pre-Cretaceous rocks, along which some profound changes have been discovered.

To the west of the fault zone in the Austin area, at depths of 100 to 650 meters (300 to 2000 feet), are Precambrian granites and strongly metamorphosed rocks, and Paleozoic rocks, mostly hard limestones.

Somewhere near the fault zone this subsurface assemblage gives way to the deeply buried remains of the Ouachita Mountain belt, produced by late Paleozoic mountain building. In Arkansas and southern Oklahoma, deeply-eroded remnants of the Ouachita Mountains are still exposed. From the study there we know that they contain a large proportion of shale and mudrocks, and similar rocks have been encountered in drill holes just east of Austin. For more information on the earlier history of Austin see **Chapter One.**

If we could backtrack in time to the late **Paleozoic Era**, we would see high mountains standing on the present site of Austin. If we could then move forward in time, watching the landscape as we move, we would witness the erosion of the mountains to a relatively flat surface. This would be accompanied by a general subsidence of the area, which allowed the Gulf of Mexico to flood areas formerly occupied by mountains and cover them with Cretaceous deposits. Later on, renewed uplifting and tilting would begin. The area to the west would rise, while we might note sinking to the east. The shoreline of the Gulf of Mexico would recede, mainly because of the filling in by deposition of material eroded from the high areas to the west.

Apparently rocks of the Ouachitas, being softer and flowing more readily under load than the western "basement" rocks, allowed the overlying Cretaceous rocks to settle east of the Balcones Fault Zone while they were relatively firmly supported on the west. The Cretaceous rocks "broke" by faulting at or near the place where Ouachita rocks comprise the "harder" basement rocks of central Texas, as shown in **Figure 46**. Note that Figure 46 shows eastward dip of the Cretaceous rocks. The actual dip of these rocks is significant, but too slight to show well in a small diagram, so it has been exaggerated.

Cretaceous rocks have moved deeper into the basin with time. Literally, they are "slipping away" from rocks further northwest, being stretched as they move along on the soft flowing rocks beneath them. This stretching in itself could be a significant part of the cause of the faulting we observe. **Figure 47** shows now stretching (extension) is associated with the formation of a graben. The stretching that caused the Balcones Fault Zone could continue only as long as the rocks beneath were able to flow. Apparently the flowage has stopped, because the Balcones Fault Zone is no longer active.

Figure 48 shows a structural cross-section through the Balcones Escarpment in Austin. This section shows the relative movements of blocks faulted. The legend for the stratigraphic units is presented in **Figure 49**. A close-up cross-section of Barton Springs is given in **Figure 56**.

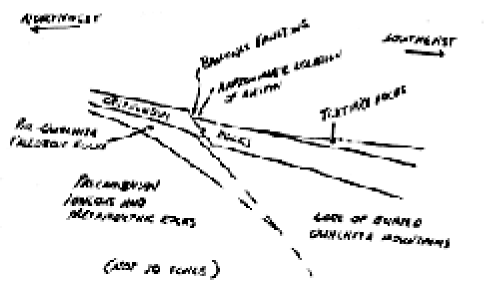


FIGURE 46

Cross-sectional Sketch of Subsurface Relations in Austin Area (M.A. Jordan)

(BIGGER)

Figure 46
Cross-sectional Sketch of Subsurface Relations in Austin Area (M.A. Jordan)

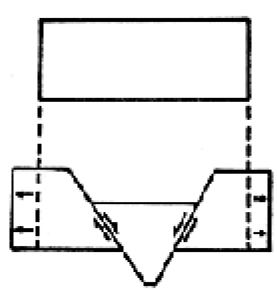


FIGURE 47

Extensional Origin of Graben (M.A. Jordan)

(BIGGER)

Figure 47
Extensional Origin of Graben (M.A. Jordan)

(BIGGER)

Figure 48
Cross-section Through Balcones Fault Zone (M.A. Jordan)

FIGURE 49
Legend to the Structural Cross-section in Fig. 48 (BIGGER)

Figure 49
Legend to the Structural Cross-section in **Fig. 48** (M.A. Jordan)

Guidebook to the Geology of Travis County

Chapter 4: Pilot Knob - a Cretaceous Volcano near Austin

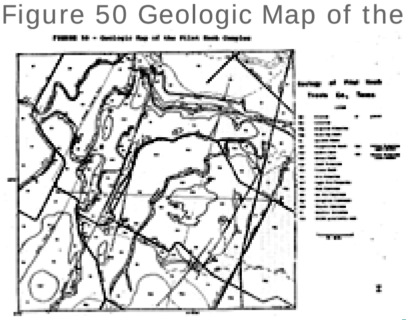
D. L. Parker

The word volcano usually summons images of snowcapped, towering mountain peaks, or remote, exotic islands in the minds of most people. Few of us living in Austin would suspect that an old volcano, its shape now extremely modified by erosional processes, lies only seven miles south of central Austin, near Bergstrom Air Force Base.

A volcano, as defined by Bullard (1962), is a vent or chimney that, at one time, has connected a reservoir of magma in the depths of the earth with the surface. The edifice of lavas and pyroclastic rocks built up around the vent is merely an expression of the activity of the volcano.

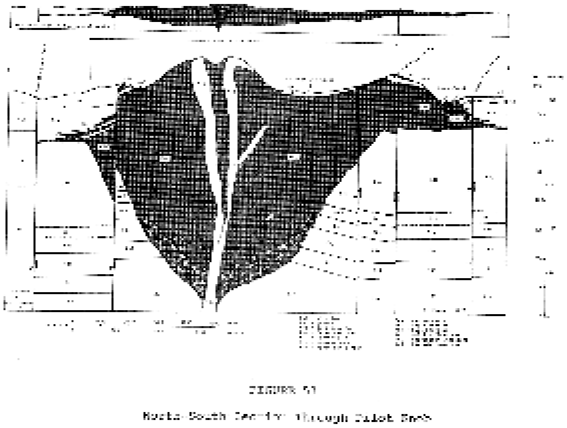
A geologic map shows that the Pilot Knob volcanic complex is about 2 miles in diameter **(Fig. 50)**. A cluster of four, small, rounded hills (including Pilot Knob proper) form a core area of the old volcano composed of trap rock, which is resistant, fine-grained mafic volcanic rock. The core area stands topographically elevated above a surrounding circular lowland, drained by Cottonmouth Creek, that is underlain chiefly by volcanic ash and other pyroclastic debris. Several smaller bodies of trap rock occur in the volcanic ash (Fig. 50). A topographic rim surrounding the Cottonmouth Creek lowland to the north is formed by sedimentary rock, mainly lithified beach sediments composed of shell fragments and reworked volcanic ash that accumulated in the shallow waters around the volcano.

Figure 50 Geologic Map of the Pilot Knob Complex



(BIGGER)

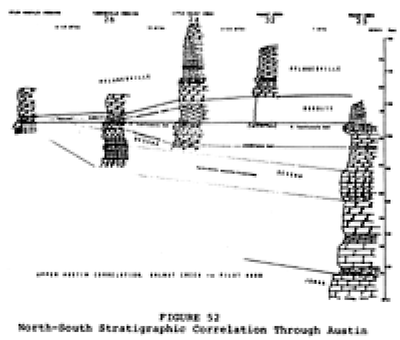
Figure 51
North-South Section Through Pilot Knob



(BIGGER)

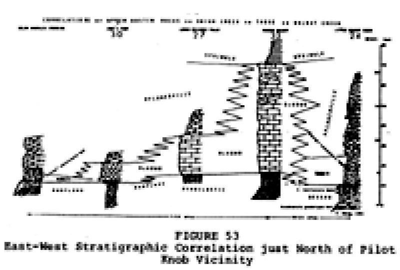
HISTORY OF THE VOLCANO

In Late Cretaceous time the area that is now central Texas was a vast marine shelE on which carbonate rocks were beiny deposited, the entire area gradually subsidiny as the sediments were laid down. Imagine what would happen if hot, molten magma, working its way to the surface, were to encounter water-laden, unconsolidated sediments. The water would be quickly heated and vaporized into steam. A large amount of water suddenly converted into steam could result in an enormous explosion. Weiss and Clabaugh (1955) hypothesized that the Pilot Knob complex was, in essence, an explosion crater, created by such a process as described above **(Fig. 51)**. Explosive eruptions continued at Pilot Knob as new magma, injected from below, encountered more water in the volcanic ash. Gradually, a mound of ash was built up over the explosion crater. Eruption of ash continued until the mound grew above the level of the shallow sea. Ash beds, now altered to clay, occur interbedded with limestone and marl of the Austin Group around Pilot Knob; these ash beds provide evidence for subaerial eruptions at Pilot Knob. The ash mound at Pilot Knob eventually built up an unstable slope on the sea bottom, and some of the ash and carbonate mud slid downhill as mudflows, ripping up the underlying carbonate mud in places and injecting itself into the carbonate mud at other places. The formation of an ash mound above sea level at Pilot Knob permitted intrusion of magma into the mound without contact with sea water, and, therefore, without explosive eruption of ash. Such magma was cooled and solidified to form the core and satellite areas of trap rock. Some of the trap rock bodies are the erosional remnants of lava flows, judging from their apparent dip away from the central core area. Cooling joints exposed on a small, rounded hill about 1,500 feet west of Pilot Knob proper suggest an original dip of that trap rock body towards the center of the core area, possibly indicating that it is the erosional remnant of a cone sheet injected outwards from a central, discordant intrusive body of magma. Exposures at other bodies of trap rock are not generally good enough to determine their exact implacement, but some, at least, are probably plugs of solidified intrusive magma. Magnetic anomalies on the northeast flank of the core area suggest a buried trap rock body within the ash mound, possibly a cone sheet or lava flow (Barker, 1970, written communication).



(BIGGER)

Figure 52
North-South Stratigraphic Correlation through Austin



(BIGGER)

Figure 53
East-West Stratigraphic Correlation Just North of Pilot Knob Vicinity

As volcanic activity diminished, beaches developed around the ash mound. One such beach deposit, now lithified and resistant to erosion, extends several miles to the north of the volcano. It crops out along Onion Creek, where it is responsible for both Upper and Lower McKinney Falls. The entire shelf continued to subside after cessation of volcanic activity, and muds of the Taylor Group gradually covered the entire volcano. During the Tertiary the central Texas area was uplifted, exposing the volcano as younger sedimentary rocks were stripped off the Cretaceous volcanic rocks. Today the terrain we observe at Pilot Knob is a reflection of the relative resistance to erosion of the different rock types that crop out in and around the volcanic complex.

DATING THE VOLCANIC ACTIVITY

Two different approaches have been used by geologists to date the volcanism at Pilot Knob. The first approach was through the stratigraphy of the rocks at and around Pilot Knob and the fossils they contain. The second approach was by isotopic age dating of the igneous rocks. The two means are very different, but supplement each other nicely, as we shall see.

STRATIGRAPHY -- The volcano at Pilot Knob exerted a profound influence on the stratigraphy of the Upper Cretaceous sedimentary rocks of the Austin area. The volcanism occurred during the deposition of the upper part of the **Dessau** and the **Burditt** formations of the Austin Chalk. These strata are only about one-third as thick near Pilot Knob as they are in localities around Austin more removed from the volcanic site. The faunal zones of the two formations, that is zones within the formations where certain fossils are particularly abundant, are also telescoped in the vicinity of Pilot Knob (Fig. 52). Two beds of altered ash occur within the **Dessau** Formation on Rinard Creek near Pilot Knob (Durham, 1955). The exact relationship of the beach rock the northern flank of Pilot Knob with the normal Austin Chalk can be demonstrated to be part of the *Exponderosa erraticosta* zone, although it may extend down to an age equivalent to the upper part of the Dessau in some areas along Onion Creek. The beach rock is now known as the **McKown** Formation of the Austin Chalk (Young, this report). Because the volcanism at Pilot Knob was contemporaneous with the deposition of the **Dessau** and **Burditt** Formations, an age of Lower Campanian [83 to 79 million years before present (Gill and Cobban, 1973)] can be interpreted for the volcanism according to the ages of the formations in the Austin Chalk as correlated by Young (1963), correlated to radiometric dated sections in the Rocky Mountain Region (Gill and Cobban, 1973).

ISOTOPIC AGE -- Baldwin and Adams (1971) utilized the potassium-argon method to determine the age of volcanism at Pilot Knob. This method is based upon the decay of the radioactive isotope of potassium (potassium 40) to argon 40, an isotope of argon, which is an inert gas. By knowing the concentration of potassium in a rock mineral and the amount of argon gas produced by radioactive decay trapped within the minerals, an age can be assigned to the rock because the decay rate of potassium 40 to argon 40 is known from experimental work (for more information on potassium-argon dating method and other isotopic age methods see Faul, 1966). The age of Pilot Knob volcanism given by Baldwin and Adams is 79.5 +/- 3 million years, and is in good agreement with the age derived by correlation with fossils to other radiometrically dated deposits (Gill and Cobban, 1973).

WHERE DOES THE MAGMA COME FROM?

One of the primary goals of petrology is to determine the origin of igneous rocks, and to decipher possible genetic relationships between different types of igneous rocks. Petrologists use a variety of different methods to answer these questions, including field relations of igneous rocks, and laboratory work on natural and "synthetic" rocks. Field relations include such observations as areal distribution, stratigraphic succession, and cross-cutting relations of different rock types. They are usually summarized by geologists in the form of geologic maps and measured sections and cross-sections. Discussion of the history of Pilot Knob presented in this report is largely based on such field observations. Laboratory work includes the study of rocks in thin section (where a thin slice of rock is examined under a microscope to determine its mineralogical composition), chemical analyses of rocks, isotopic studies, and high pressure and temperature experiments. The latter are made in specially constructed "bombs" -- high pressure and temperature vessels -- in which conditions deep within the earth -- the source of magma -- can be simulated.

The igneous rocks of the Pilot Knob volcano have not, as yet, been subjected to rigorous petrological study, although such studies are in progress. Similar rocks near Uvalde, Texas, of about the same age, have been studied (Spencer, 1969). The Uvalde rocks are of the same igneous province as the Pilot Knob rocks; both are centers in a chain of volcanic and intrusive complexes that parallel the buried Ouachita structural belt (Grunig, this report) in central and south Texas. The Ouachita belt may have provided a zone of crustal weakness where magma could rise from great depths through the crust to the surface.

Spencer (1969) determined that two types of magma were generated in the earth's upper mantle by partial melting of mantle rocks. One of these magma types is basaltic in composition, composed of plagioclase, titanium-rich pyroxene, and olivine. The other magma type crystallized to nepheline, melilite, pyroxene, and, in some of the rocks, plagioclase. Some nepheline-bearing igneous rocks contain rounded inclusions of spinel peridotite, an ultramafic rock that may represent fragments of the upper mantle incorporated into the magma during its ascent to the surface. Most of the igneous rocks we observe at the surface probably are not representative of the original magmas formed in the mantle; certain processes, such as separation of phenocrysts from the liquid from which they crystallized have altered their original chemical compositions at depths shallower than the mantle.

By inference, the rocks at Pilot Knob crystallized from partial melts of the upper mantle. Only rocks of the second series have been discovered at Pilot Knob; no basaltic rocks have been located (Barker, 1974, written communication). No mantle fragments have been located in Pilot Knob igneous rocks, but their presence is suspected, and some of the olivine phenocrysts in the rocks may be fragments derived from the upper mantle.

HOW TO SEE PILOT KNOB

Pilot Knob can be reached by driving out Highway 183 past Bergstrom Air Force Base (soon to be Austin's-**Bergstrom International Airport**). As you cross Onion Creek the Knob is visible ahead to your right. A circuit of the volcanic complex can be made by turning off Highway 183 onto Elroy Road (to the right) and following Elroy Road to the intersection with Bluff Springs Road, where a left turn leads back to Highway 183. Elroy Road closely follows the northern topographic rim of the volcano formed by the escarpment of the Cretaceous beach rock mentioned earlier. The lowland drained by Cottonmouth Creek and underlain by soft, easily eroded volcanic ash and other pyroclastic deposits, and the central core area formed by the resistant trap rock are easily visible to the south of Elroy Road. About 2/3 of a mile east of the intersection of Bluff Springs Road with Elroy Road, the trap rock of south Pilot Knob crops out along the road. This rock is very similar to that which forms the center of the volcano, and may represent the eroded remnant of a lava flow erupted along the flanks of the volcano or having flowed down the south side from the apex.

Except for the road margins Pilot Knob volcano lies entirely on private land. Always obtain permission from landowners before entering private property. Please do not trespass, as this only serves to erode relationships with landowners and makes it difficult, and sometimes impossible, for people who come later to visit outcrops. In the example of Pilot Knob little can be gained by going to the top. The trap rock can be observed on Bluff Springs Road, and the topography and total aspect of the old volcano can be observed much better from Elroy Road.

Chapter 5: Collecting Localities for Fossils in Austin

Keith Young

Many fossils have been collected in the Austin area. Some of the localities listed in the following pages can be collected without permission. Other localities require permission. The fossils listed are those that have been found at these areas. Undoubtedly not all have been listed.

GLEN ROSE LIMESTONE

West side of Mount Bonnell, Travis County, Texas, along Mount Bonnell Road.

FORAMINIFERIDA

Lituola subgoodlandensis (Vanderpool)

Haplophragmoides globosa Lozo

H. trinitensis Lozo

Buccicrenata subgoodlandensis (Vanderpool)

Tritaxia glenrosensis

Orbitolina texana (Romer)

PELECYPODA

Neithea irregularis (Bose)

Monopleura sp.

Ceratostreon weatherfordensis (Cragin)

GASTROPODA

Nerinea austinensis (Romer)

Nerinoides sp.

ECHINOIDEA

Loriola texana (Romer)

GLEN ROSE LIMESTONE

East Bull Creek, just east of old Spice Springs Road Crossing, east of West Loop Bridge, Travis County, Texas

FORAMINIFERIDA

Haplophragmoides globosa Lozo

H. trinitensis Lozo

Lituola subgoodlandensis (Vanderpool)

L. camerata Lozo

Ammobaculites goodlandensis Cushman & Alexander

A. laevigata Lozo

T. subcretaceus Cushman & Alexander

Buccicrenata subgoodlandensis (Vanderpool)

Flabellammina alexanderi Cushman

Tritaxia glenrosensis fft-ead

Orbitolina texana (Romer)

Coskinolinoides texanus Keijzer

Dictyoconus walnutensis (Carsey)

Barkerina barkerensis Frizzell & Schwartz

Vitrewebbina laevis (Sollas)

Conorbina conica Lozo

PELECYPODA

Trigonia crenulata (Romer)

Anatina hanseni M. Shitney

Pholadomya knowaltoni Hill

Pleuromya henseli Hill

Ceratostreon weatherfordensis (Cragin)

Ostrea wardi Hill & Vaughan

ECHINOIDEA

Loriola texana (Romer)

ALGAE

Porocystis globularis (Giebel)

GLEN ROSE LIMESTONE

Upper part, between West Bull Creek and East Bull Creek, along Northwest Loop, Austin, Travis County, Texas

PELECYPODA

Igonearca sp.

Modiolus sp.

Trigonia sp.

Arctica roemeri (Cragin)

Pholadomya sp.

Ceratostreon weatherfordensis (Cragin)

GASTROPODA

Lunatia (?) sp.

ECHINOIDEA

Loriola texana (Romer)

VERMES

Serpula sp.

WALNUT FORMATION - Bull Creek Member

Highway 2222, east of Hickmantown, along the hill below the Feed Lot Cave

PELECYPODA

Gastrochaena sp.

Texigryphaea mucronata (Bagg)

Ceratostreon texanum (Romer)

WALNUT FORMATION - Bee Cave Member

City Park Road, at top of hill south of Bull Creek, Travis County, Texas

FORAMINIFERIDA

Dictyoconus walnutensis (Carsey)

PELECYPODA

Neithea irregularis (Bose)

Texigryphaea mucronata (Gabb)

Ceratostreon texanum (R'O'mer)

GASTROPODA

Tylostoma sp.

CEPHALOPODA

Metengonoceras ambiguum (Hyatt)

M. hilli (Hyatt)

ECHINOIDEA

Loriola whitneyi Ikins

Enallaster texanum (Romer)

WALNUT FORMATION - Bee Cave Member

Just south of Cat Mountain along Walnut Clay Drive, Austin, Travis County, Texas

PELECYPODA

Paleopinna comanchensis (Cragin)

Paraesa sp.

Texigryphaea mucronata (Gabb)

Ceratostreon texanum (Romer)

GASTROPODA

Alipes sp.

Nerinoides sp.

Tylostoma sp.

ALGAE

Porocystis globularis (Giebel)

WALNUT FORMATION - Bee Cave Member

Travis County Park in Northwest Hills along Balcones Trail, one block south of Hart Lane, Austin, Travis County, Texas

FORAMINIFERIDA

Dictyoconus walnutensis (Carsey)

PELECYPODA

Neithea irregularis (Bose)

Paraesa sp.

Texigryphaea mucronata (Gabb)

Ceratostreon texanum (Romer)

ECHINOIDEA

Loriola whitneyi (Ikins)

Tetragramma taffi Cragin

Enallaster texanus (Romer)

WALNUT FORMATION - Bee Cave Member

Northwest Loop just east of Spicewood Springs ramp, Austin, Travis County, Texas

FORAMINIFERIDA

Dictyoconus walnutensis (Carsey)

PELECYPODA

Igonearca sp.

Neithea irregularis (Bose)

Granocardium speciosum (Bose)

Texigryphaea mucronata (Gabb)

Ceratostreon texanus (Romer)

GASTROPODA

Alipes sp.

Turritella sp.

ECHINOIDEA

Tetragramma taffi Craqin

Enallaster texanus (Romer)

WALNUT FORMATION - Cedar Park Member

Bee Cave Road at intersection with West Loop, northeast side of road along cliff, Austin, Travis County, Texas

FORAMINIFERIDA

Dictyoconus walnutensis (Carsey)

PELECYPODA

Texigryphaea mucronata (Gabb)

Ceratostreon texanum (R'o'mer)

ALGAE

verticellate algae

EDWARDS LIMESTONE

Bluff south of Red Bud Trail along the west bank of the Colorado River, Austin, Travis County, Texas

PELECYPODA

Chondrodonta munsoni (Hill)

*Lucina acutelineata*Romer

Monopleura marcida White

M. pinguiscula White

M. texana Romer

Toucasia patagiata (White)

T. texana

Caprinuloidea crassifibra (Romer)

Eoradiolites davidsoni Hill

GASTROPODA

Amauropsis avellana (Romer)

Architectonica planorbis (Romer)

Ceritella glabra Stanton

C. proctori (Cragin)

Cerithium austinense Romer

C. bartonense Stanton

C. coloradoense Stanton

C. kickapooense Stanton

C. obliterogranosum Romer

C. pecosense Stanton

C. shattucki Stanton

Epitonium austinense Stanton

Margarites bartonensis Stanton

M. bartonensis vaughani Stanton

M. browni (Cragin)

Monodonta bartonensis Stanton

M. minuta Stanton

Nerinea pellucida Cragin

Nerita apparata Cragin

Nerinoides austinensis (Romer)

N. gemmata (Stanton)

N. gemmata parvilineata (Stanton)

N. pseudoconvexa (Stanton)

N. subula (R6mer)

Pileolus septangularis Stanton

Rimula vaughani Stanton

Solariella serrata Stanton

Tainostom (?) austinensis Stanton

Trochactaeon parvus Stanton

T-rochus texanus (Romer)

Triforis antiquus Stanton

operculae of neritid gastropods

COELENTERATA

Cladophyllia furcifera (Romer)

Pleurocora texana Romer

P. coalescens Romer

Coelosmilia americans Romer

Parasmilia austinensis Romer

GEORGETOWN LIMESTONE

Pease Park, in Shoal Creek, opposite the hill on Martin Luther King Jr. (19th) Street, Austin, Travis County, Texas

GASTROPODA

Turritella austinensis Ellisor

T. bonnellensis Ellisor

T. georgetownensis Ellisor

CEPHALOPODA

Plesioturrilites brazoensis (R'O'mer)

Mortoniceras wintoni (Adkins)

Durnovarites adkinsi Young

Graysonites adkinsi Young

GEORGETOWN LIMESTONE

Huck's Slough, just west of the Albert Ulrich Water Purification Plant on the north side of 34th Street, Austin, Travis County, Texas

FORAMINIFERIDA

Textularia rioensis Carsey

T. washitensis Carsey

Gaudryina boaquensis Loeblich & Tappan

Hedbergella delrioensis (Carsey)

H. washitensis (Carsey)

PELECYPODA

Pecten bonnellensis Kniker

Neithea altana Kniker

N. bellula (Cragin)

N. georgetownensis Kniker

N. subalpina (Bose) var. *linki* Kniker

N. subirregularis Kniker

N. texana (Romer)

N. theodori Kniker

Neithella wrighti (Shumard)

Texigryphaea (?) gibberosa (Cragin)

Texigryphaea washitaensis (Hill)

Ceratostreon walkeri (White)

Ilymatogyra arietina (Romer)

Arctostrea sp. aff. A. carinata (Lamarch)

GASTROPODA

Turritella bonnellensis Ellisor

T. planilateris Conrad

T. simondsi Ellisor

CEPHALOPODA

Eopachydiscus brazoensis (Shumard)

Pervinguieria equidistans (Cragin)

Drakeoceras kummeli Young

D. lasswitzi Young

BRACHIOPODA

Kingena wacoensis (Shumard)

DEL RIO CLAYSTONE

Just above contact with Georgetown Limestone, Pease Park, about Martin Luther King Jr. (19th) Street and Shoal Creek, Austin, Travis County, Texas

FORAMINIFERIDA

Reophax incompta Loeblich & Tappan

Haplophragmoides concavus (Chapman)

Ammobaculites dentonensis Tappan

Ammobaculoides plummerae Loeblich

Triplasia excavatum (Reuss)

Acruliammina longa (Tappan)

Spiroplectammina longa Lalicker

Textularia rioensis Carsey

Trochammina wickendeni Loeblich

Gaudryina bosquensis Loeblich & Tappan

Eggerella graysonensis Tappan

Massilina planoconvex Tappan

Nodosaria lepida Reuss

N. obscura Reuss

Citharina complanata (Reuss)

Dentalina debilis (Berthelin)

D. hanunensis (Franke)

D. striatifera Tappan

Lagena apiculata (Reuss)

Denticulina gaultina (Berthelin)

Marginulina tenuissima Reuss

M. tripleura (Reuss)

Guttulina expolita Bullard

Histopomphus cervicornis (Chapman)

H. redriverensis (Tappan)

Ramulina globulifera Brady

Neobulimina minima Tappan

Bulimina nannina Tappan

Discorbus minima Vieaux

D. minutissima Tappan

Valvulineria asterigerinoides Plummer

Spirillina minima Schacko

Turrisipirillina subconica Tappan

Patellina subcretacea Cushman & Alexander

Heterohelix washitensis (Tappan)

Globorotalia delrioensis Plummer

G. marginaculeata Loeblich & Tappan

Globigerina planispira Tappan

G. ruqosa Plummer

Fursenkoina minuta (Cushman)

Gyroidina loetterlei Tappan

Anomalina petita Carsey

DEL RIO CLAYSTONE

Middle part, at the west bank of Shoal Creek about 32nd Street, Austin, Travis County, Texas

FORAMINIFERIDA

Reophax minuta Tappan

Haplophragmoides concavus (Chapman)

Ammobaculites cuyleri Tappan

A. euides Loeblich & Tappan

A. goodlandensis Cushman & Alexander

A. subcretaceous Cushman & Alexander

Ammobaculoides gainesvillensis Loeblich & Tappan

Spiroplectammina longa Lalicker

Textularia rioensis Carsey

T. washitensis Carsey

Trochammina wickendeni Loeblich

Gaudryina bosquensis Loeblich & Tappan

Gaudryinella delrioensis Plummer

Eggerella graysonensis (Tappan)

Massilina planoconvexa Tappan

Nodosaria amphioxys Reuss

N. barkeri Vieaux

N. lepida Reuss

N. obscura Reuss

N. scotti Tappan

Chrysalogonium granti (,Plummer)

Citharina complanata (Reuss)

C. complanata persistriata (Tappan)

C. duckcreekensis (Tappan)

C. kochii (Romer)

C. recta (Reuss)

Dentalina communis (d'Orbigny)

D. debilis (Berthelin)

D. striatifera (Tappan)

Lagena apiculata (Reuss)

L. sulcata Walker & Jacob

Lenticulina gaultina (Berthelin)

Marginulina enigmata (Bullard)

M. tennuissima Reuss

Saracenaria cushmani Tappan

S. duckcreekensis Tappan

Lingulina furcillata Berthelin

L. nodosaria Reuss

Glandulopleurostomella ozawai (Tappan)

*Guttulina expolita*Bullard

Pseudopolymorphina roanokensis Tappan

Pyrulina cylindroid (Romer)

Histopomphus cericornis (Chapman)

H. redriverensis (Tappan)

Ramulina globulifera Brady

Washitella typica Tappan

Tristix excavata (Reuss)

Neobulimina minima Tappan

Bulimina nannina Tappan

Discorbis minima Vieaux

D. minutissima Tappan

Valvulineria asterigerinoides Plummer

Spirillina minima Schacko

Guembelitria harrisi Tappan

Heterohelix washitensis (Tappan)

Globorotalia delrioensis Plummer

Hedbergella planispira (Tappan)

H. rugosa (Plummer)

H. delrioensis (Carsey)

H. washitensis (Carsey)

Pleurostomella watersi Cushman

Fursenkoina minuta (Cushman)

Anomalina petita Carsey

PELECYPODA

Ilymatogyra arietina (Romer)

Ostrea perversa Cragin

CEPHALOPODA

Plesioturrilites brazoensis (Romer)

Graysonites spp.

DEL RIO CLAYSTONE

Upper part, at the intersection of Barton Springs Road and Lamar Boulevard, Austin, Travis County, Texas

FORAMINIFERIDA

Cribratina texana (Conrad)

Ammobaculites dentonensis Tappan

Flabellammina alexanderi Cushman

Placopsilina minima Tappan

Acruliaramina longa (Tappan)

Textularia rioensis Carsey

Trochammina wickendeni Loeblich

Eggerella graysonensis (Tappan)

*Massilina planoconvexa*Tappan)

Nodosaria lepida Reuss

N. obscura Reuss

Citharina complanata persistriata (Tappan)

C. duckcreekensis (Tappan)

C. recta (Reuss)

Dentalina communis (d'Orbigny)

D. debilis (Berthelin)

D. triatifera (Tappan)

Lagena apiculata (Reuss)

Lenticulina gaultina (Berthelin)

Marginulina enigmata (Bullard)

M. tripleura (-Reuss)

Glandulopleurostomella ozawai (Tappan)

Histopomphus cervicornis (-Chapman)

*Ramulina pullardae*Frizzell

R. globulifera BFa-dy

Tristix acutanglula (Reuss)

Neobulimina minima Tappan

Bulimina nannina Tappan

Discorbis minima Vieaux

D. minutissima Tappan

Heterohelix washitensis (Tappan)

Globorotalia delrioensis Plummer

G. marginaculeata Loeblich & Tappan

Hedbergella rugosa (Plummer)

H. planispira (Tap-pan)

Gyroidina loetterlei Tappan

Anomalina petita Carsey

BUDA LIMESTONE

Bear Creek, south of Manchaca, Travis County, Texas

PELECYPODA

Pecten manchacensis Kniker

Neithea budensis Kniker

N. simondsi Kniker

N. whitneyi Kniker

Ceratostreon walkeri (White)

GASTROPODA

Turritella budaensis Whattuck

T. manchacensis Ellisor

CEPHALOPODA

Mantelliceras budaense Adkins

Budaiceras eleganitor (Lasswitz)

Faraudiella roemeri (Lasswitz)

COELENTERATA

Actinostromaria dehorneae Wells

Axosmilia quaylei (Wells)

A. whitneyi (Wells)

PORIFERA

Verticellites budaensis Wells

BUDA LIMESTONE

West Bouldin Creek at the Missouri Pacific Railroad track, Austin, Travis County, Texas

PELECYPODA

Granocardium budaensis Shattuck

Homomya vulgaris Shattuck

GASTROPODA

Cerithium texanum Shattuck

Turritella budaensis Shattuck

ECHINOIDEA

Goniopygus sp.

BUDA LIMESTONE

Between Barton Creek and Lamar Boulevard, along the south side of Barton Springs Road, Austin, Travis County, Texas

PELECYPODA

Barpatia simondsi Whitney

Trigonia emoryi Conrad

Protocardia texana Conrad

GASTROPODA

Cerithium shumardi Whitney

Cinulia pelleti Whitney

Turritella bartonensis Ellisor

T. budaensis Shattuck

Tylostoma hilli Whitney -.

T. harrisi WhiTney

CEPHALOPODA

Plesioturrilites brazoensis (Romer)

Budaiceras texanum (Shattuck)

ARTHROPODA

Graptocarcinus texanus Romer

BUDA LIMESTONE

Shoal Creek, Austin, Travis County, Texas

PELECYPODA

Barbatio simondsi Whitney

Modiolus austinensis (Whitney)

Gervillia invaginata White (?)

Neithea guinquecostatus (Sowerby)

N. roemeri (Hill)

Neithella wrighti (Shummard)

Spondylus cragini Whitney

S. texanus Whitney

Anomia geniculata Whitney

Lima wacoensis Romer

Trigonia emorci Conrad

Stearhsia robinsi White

Granocardium budaense Shattuck

Protocardia texana Conrad

Anatina austinensis Shattuch

A. texana Shattuck

Ptychomya ragsdalei (Cragin)

"Isocardia medialis" Conrad

Meretrix leonensis (Conrad)

Paraesa austinensis (Whitney)

Gastrochaena ruperti (Whitney)

Pholadomya roemeri Shattuck

Homomya budaensis Whitney

H. vulgaris Shattuck

Pachymya budaensis Whitney

Texigryphaea roemeri (Marcou)

Exogyra clarki Shattuck

Arctostrea carinata (Lamarck)

GASTROPODA

Cerithium hilli Whitney

C. shumardi Whitney

C. stantoni Whitney

C. (?) texana Shattuck

Cinulia conradi Whitney

Cylindrites whitei Whitney

Fusus simondsi Whitney

F. texanus Shattuck

Harpagodes shumardi (Hill)

Pleurotomaria stantoni Shattuck

Turritella bartonensis Ellisor

T. budaensis Shattuck

T. felteri Ellisor

T. shippi Ellisor

Tylostoma harrisi Whitney

T. hilli Whitney

Volutilithies austinensis Whitney

CEPHALOPODA

Paracymatoceras hilli (Shattuck)

Plesioturrilites brazoensis (Romer)

P. roembri (Whitney)

Turrilites wysogorski Lasswitz

Budaiceras curvatum (Lasswitz)

B. elegantior (Lasswitz)

B. evae (Lasswitz)

B. hyatti (Shattuck)

Faraudiella roemeri (Lasswitz)

F. texanum (Shattuck)

Hantelliceras budaense Adkins

M. saxbyi (Sharpe)

ECHINOIDEA

Cottaldia rotula Clark

Holectypus planatus Romer

Nucleolites angustatus (Clark)

Enallaster bravoense Bose

E. traski Witney

Hemiaster calvini Clark

COELENTERATA

Actinostromaria dehorneae Wells

Astrocoenia budaensis Wells

Epistreptophyllum budaensis (Wells)

Trochoseris shattucki Wells

Trocharea bakerae (Wells)

Dimorpharaea manchacaensis Wells

Budaia travisensis Wells

Axosmilia saxifisi (Wells)

Montastrea texana (Vaughan)

Caryophillia comanchei Wells

PORIFERA

Verticellites budaensis Wells

ARTHROPODA

Graptocaricinus texanus Romer

EAGLE FORD FORMATION

Travis-Wi.lliamson County line, east of Interstate Highway 35

CEPHALOPODA

Baculites gracilis Shumard

Proplacenticeras pseudoplacenta (Hyatt)

Kanabiceras septemseriatim (Cragin)

Pseudaspidoceras sp. aff. P. armatum (Pervinquiere)

Coilopoceras chispaense Adkins

C. eaglefordense Adkins

C.springeri Hyatt

Prionocyclus hyatti Stanton

EAGLE FORD FORMATION

West Bouldin Creek-, Austin, Travis County, Texas

FORAMINIFERIDA

Heterohelix globulosa (Ehrenberg)

Hedbergella rugosa (Plummer)

PELECYPODA

Nicaisolopha lugubris (Conrad)

CEPHALOPODA

Coilopoceras eaglefordense Adkins

Prionocyclus hyatti Stanton

EAGLE FORD FORMATION

Along tributary to Walnut Creek, Oak Haven Waterfall, Watters Park, Austin, Travis County, Texas

CEPHALOPODA

Baculites gracilis Shumard

Scaphites morrowi Jeletzky

Kanabiceras septemseriatim (Cragin)

Pseudaspidoceras sp. aff. P. armatum (Pervinquiere)

Pseudaspidoceras adkinsi (Kummel and Decker, 1954)

Coilopoceras chispaense Adkins

C. colleti Hyatt

C. eaglefordense Adkins

C. springeri Hyatt

Prioncyclus hyatti Stanton

ATCO FORMATION

West Bouldin Creek, Austin, Travis County, Texas

PELECYPODA

Inoceramus subquadratus Schulter

CEPHALOPODA

Peroniceras haasi Young

VINSON FORMATION

Hancock Golf Course, Waller Creek, Austin, Travis County, Texas

PELECYPODA

Idonearca sp.

Exogyra sp. aff, E. aquila Goldfuss

Rhynchostreon.(?)-sp. aff. R. suborbiculata (Lamarck)

CEPHALOPODA

Texanites texanus (Romer)

VINSON FORMATION

Vinson Creek, just south of Bluff Springs Road, mile south of Onion Creek Bridge, Travis County, Texas

PELECYPODA

Exogyra sp. aff. E. aquila Goldfuss

Rhynchostreon (?)-sp. aff. R. suborbiculata (Lamarck)

Aegerostria sp.

JONAH FORMATION

San Gabriel River crossing at Jonah, Williamson County, Texas

PELECYPODA

Idonearca sp.

Spondylus quadalupae Romer

Pychodonte aucella (Romer)

Actinostreon travisana (Stephenson)

CEPHALOPODA

Texanites americanus (Lasswitz)

ECHINOIDEA

Hemiaster texanus Bose

DESSAU FORMATION

Little Walnut Creek, upstream from the bridge at Highway 290, Austin, Travis County, Texas

PELECYPODA

Inoceramus spp.

Spondylus guadalupae Romer

Pychodonte aucella (Romer)

Exogyra laeviuscula Romer

E. ponderosa Romer

E. tigrina Stephenson

CEPHALOPODA

Glyptoxoceras ellisoni Young

Smedaliceras durhami Young

Scaphites sp. cfr. S. leei Reeside

Submortoniceras tequesquetense Young

BRACHIOPODA

Terebratulina quadalupae (ROmer)

CRINOIDEA

Marsupites americanus Springer

DESSAU FORMATION

Old Turnersville Road crossing of Rinard Creek, southwest of Pilot Knob, Travis County, Texas

PELECYPODA

Pychodonte aucella (Romer)

Exogyra laeviuscula Romer

E. tigrina Stephenson

CEPHALOPODA

Anapachydiscus sp.

Suboftoniceras tequesquetense Young

BRACHIOPODA

Terebratulina guadalupae (Romer)

DESSAU FORMATION

Brushy Creek, just downstream from old iron bridge on Hutto-New Sweden Road, Williamson County, Texas

PELECYPODA

Idonearca sp.

Inoceramus spp.

Pychodonte aucella (Romer)

Exogyra laeviuscdla Romer

E. ponderosa Romer

E. tigrina Stephenson

CEPHALOPODA

Eutrephoceras campbelli Meek

Glyptoxoceras ellisoni Young

Texanites shiloensis Young

Bevanites bevahensis Collignon

Submortoniceras tequesquetense Young

Australiella pattoni Young

Larroisiceras dentatocarinatum (Romer)

Pseudoshloenbachia mexicana (Renz)

BRACHYOPODA

Terebratulina guadalupae (Romer)

BURDITT FORMATION

Little Walnut Creek, just upstream from the bridge at Highway 290, Austin, Travis County, Texas

FORAMINIFERIDA

Citharina texana (Cushman)

Marginotruncana concavata (Cushman)

PELECYPODA

Ostrea centerensis Stephenson

CEPHALOPODA

Smedaliceras durhami Young

Parapuzosia boesei Scott & Moore

Eupachydiscus jimenezi (Renz)

CRINOIDEA

Marsupites americanus Springer

BURDITT FORMATION

Old Turnersville Road crossing of Rinard Creek, south- west of Pilot Knob, Travis County, Texas

PELECYPODA

Ostrea centerensis Stephenson

CEPHALOPODA

Smedaliceras durhami Young

Parapuzosia boesesi Scott & Moore

Eupachydiscus jimenezi (Renz)

Submortoniceras vanuxemi (Morton)

Menabites densinodosus (Renz)

PFLUGERVILLE FORMATION

Bridge over Little Walnut Creek at Springdale Road, Austin, Travis County, Texas

FORAMINIFERIDA

Manorella proteus Grice

Siphogaudryina austinana Cushman

Pseudogaudryina ellisorae Cushman

Dentalina alternate (Jones)

Frondicularia watersi Cushman

F. inversa Reuss

Tseudofrondicularia intermittens (Reuss)

P. bidentata (Cushman)

Kyphopyxa christneri (Carsey)

Lagena acuticosta Reuss

L. globosa Montagu

*L. hispida*Reuss

Saracenaria triangularis (d'Orbigny)

Ramulina aculeata (d'Orbigny)

Buliminella carseyae Plummer

Eouviqerina austinana Cushman

Pseudouvigerina plummerae Cushman

Hasteri voluta (White)

Globotruncana fornicate Plummer

Planulina texana Cushman

Cibicides constrictus (Hagenow)

Anomalina nelsoni (Berry)

PELECYPODA

*Neithea casteeli*Kniker

Idonearca sp.

Exogyra ponderosa (Romer)

E. ponderosa erraticostata Stephenson

CEPHALOPODA

Menapites walnutensis Young

BRACHIOPODA

Terebratulina guadalupae (Romer)

PFLUGERVILLE FORMATION

Little Walnut Creek, upstream from the bridge at Highway 290, Austin, Travis County, Texas

FORAMINIFERIDA

Gaudryina austinana (Cushman)

G. eliisorae (Cushman)

Pseudogaudryinella capitosa (Cushman)

Pseudoclayulina clavata (Cushman)

Loxostomoides cushmani (Wickendeni)

PELECYPODA

Exogyra ponderosa erraticostata Stephenson

Aegerostria sp.

PFLUGERVILLE FORMATION

South bank of Walnut Creek at old Sprinkle Road crossing, north of Austin, Travis County, Texas

PELECYPODA

Inoceramus sp.

Pychodonte aucella (Romer)

Exogyra ponderosa Romer

E. ponderosa erraticostata Stephenson

Aegerostria sp.

Actinostreon travisana (Stephenson)

CEPHALOPODA

Baculites sp. indet.

Delawarella delawarensis (Morton)

McKOWN FORMATION

McKown Quarry, below McKinney Falls State Park, north bank of Onion Creek, Travis County, Texas

PELECYPODA

Exogyra ponderosa ertaticostata Stephenson

CEPHALOPODA

Delawarella delawarensis (Morton)

SPRINKLE FORMATION

About seven feet above the base, on Little Walnut Creek, 0.2 miles downstream from the bridge on Springdale Road, Travis County, Texas

FORAMINIFERIDA

Spiroplectammina lalickeri Albritton & Phleger

Clavulina clavata (Cushman)

Pseudogaudryinella capitosa serrulata (Cushman)

Nodosaria affinis Reuss

Dentalina legumen Reuss

Frondicularia intermittens Reuss

Hyphopyxa christneri (Carsey)

Lagena acuticosta Reuss

L. hispida Reuss

Buliminella canadaensis Plummer

Neobulimina canadensis Cushman & Wickenden

Eouvlgerina aculeata Cushman

Bulimina exigua Cushman & Parker

B. rudita Cushman & Parker

Valvulineria infrequens morrow

Heterohelix globocarinata (Cushman)

H. plummerae (Loetterle)

Globotruncana cretacea Cushman

Fursenkoina tegulata (Reuss)

Loxostomum cushmani Wickenden

*Nonionella austinana*Cushman

Gyroidina depressa (Altn)

Planulina texana Cushman

PECAN GAP CHALK

Walnut Hill Area, east of Austin, Travis County, Texas

FORAMINIFERIDA

Ammodiscus cretaceus (Reuss)

Haplophragmoides excavatus Cushman & Waters

Ammobaculites stephensoni Cushman

Clavulinoides disjunctus (Cushman)

C. trilaterus (Cushman)

C. whitei (Cushman & Jarvis)

Spiroplectammina cretosa Cushman

S.semicomplanata (,Carsey)

Bolivinopsis rosula (Ehrenberg)

Textularia ripleyensis Berry

T. subconica Franke

Gaudryina bentonensis (Carmen)

Pseudogaudryina ellisorae Cushman

Clavulina clavata (.Cushman)

Heterostomella americans Cushman

H. austinana Cushman

Tritaxia ellisorae Cushman

Arenobulimina americana Cushman

Dorothia conula (Reuss)

D. oxycona (Reuss)

Eggerella trochoides (Reuss)

Nodosaria amphioxys Reuss

N. navarroana Cushman

N. obscura Reuss

N. caudigera (Schwager)

Chrysalogonium eximium Cushman

C. texanum Cushman

Citharina multicostata (Cushman)

C. wadei (,Kelley)

Dentalina aculeata Cushman

D. alternate (Jones)

D. planata Cushman

Page 128 missing

C. constrictus (Hagenow)

Plearostomella alexanderi (Cushman)

P. stephensoni (Cushman

P. subnodosa (Reuss)

Nodosarella gracillima Cushman

Loxostomum cushmani Wickenden

L. eleyi (C shman)

L. plaitum (Carsey)

Pullenia americans Cushman

Allomorphina minuta Cushman

Nonionella austinana Cushman

Gyroidina depressa (Alth)

G. globosa (Hagenow)

Globorotalites conicus (Carsey)

G. umbilicates (Loetterle)

Anomdlina ammonoides (Reuss)

A. clementiana (d'Orbigny)

A. henbesti Plummer

A. nelsoni (Berry)

A. inguis Jennings

PELECYPODA

Inoceramus spp.

Atreta cretacea (Stephenson)

Pychodonte vesicularis (Lamarch)

Exogyra ponderosa erraticostata Stephenson

CEPHALOPODA

Exiteloceras sp.

Baculites taylotensis Adkins

Hoplitoplacenticeras vari (Marrot)

Pachydiscus travisi (Adkins)

ECHINOIDEA

Echinocorys texanus (Cragin)

BERGSTROM FORMATION

Concretion zone near gate to Sandahl's Farm near Manda, Travis County, Texas

PELECYPODA

Nuculana tarensis Stephenson

Paleopinna laqueata Conrad

Inoceramus proximus Tuomy

Lima reticulate Forbes

Trigonia eufalensis Gabb

Cardium cliffwoodensis Weller

C. penderense Stephenson

C. ripleyanum

C. tenuistriatum (Whitfield)

C. vaughani Stephenson

Cymbophora triqonalis Stephenson

Glossus cliffwoodensis Weller

Cyprimeria depressa Conrad

Liophistna (Cymella) bella (Conrad)

Agerostria falcata (Morton)

GASTROPODA

Amauropsis meekana Whitfield

Anchura johnsoni Stephenson

A. pergracilis Johnson

A. solitaria Whitfield

Cypraea mortoni Gabb

Gyrodes altispira (Bagg)

G. alveata Conrad

Morea cancellaria Conrad

Natica abyssian Morton

N. globulella Whitfield

Polinices (Euspira) halli (Gabb)

Pyrifusus marylandicus Gardner

Pyropsis reileyi Whitfield

Scalaria hercules Whitfield

CEPHALOPODA

Eutrephoceras dekayi (Morton)

Baculites anceps Lamarck

B. asper Morton

B. ovatus Say

Placenticeras intercalate Meek

P. placenta (Dekay)

Manambolites ricensis Young

COELENTERATA

Micrabacia americans Meek & Hayden

M. cribraria Stephenson

M. rotatilis georgiana Stephenson

M. rotatilis Stephenson

Trochocyathes conoides (Bagg & Horn)

CORSICANA FORMATION

Cottonwood Creek Valley, northeast Travis County, Texas

FORAMINIFERIDA

Bulimina aspera Cushman & Parker

B. ovulum Reuss

Epistomella glabrata (Cushman)

Siphonina prima Plummer

Planulina correcta (Carsey)

Cibicides harperi (Sandidge)

Pleurostomella alexanderi immensia Cushman

Loxostomum plaitum (Carsey)

Anomalia nelsoni Berry

PELECYPODA

Crenella serica Conrad

Lima kimbroensis Stephenson

Venericardia webbervillensis Stephenson

Exogyra costata (Say)

VERMES

Hamqlus onyx Morton

CORSICANA FORMATION

In gully in west facing-slope on Cottonwood Creek Valley, 1/4 mile west of Kimbro and 2 miles south of Manda, Travis Co unty, Texas

FORAMINIFERIDA

Haplophragmoides calculus Cushman & Waters

Ammobaculites coprolithiformis (Schwager)

Trochammina diagonis (Carsey)

Dorthia bullata (Carsey)

D. glabrata (Cushman)

Plectina waters Cushman

Nodosaria lagenoides (Olszewaki)

Citharina multicostata Cushman

C. webbervillensis (-Carsey)

Dentalina basiplanata Cushman

D. confluens Reuss

Lenticulina navarroensis (Plummer)

L. spissocastatus Cushman

Marginulina silicula (,Plummer)

Saracenaria saratogana Howe & Wallace

Vaginulina cretacea Plummer

Pseudopolymorphina- cuvleri Plummer

Pyrulina cylindroides (R6mer)

Pseudouvigerina seligi (Cushman)

Heterohelix costulata (Cushman)

H. globulosa (Ehrenberg)

Gublerina carseyae (Plummer)

Nonionella robusta Plummer

CORSICANA FORMATION

Jones' Crossing of Onion Creek, from 80-foot bluff downstream from Austin-Bastrop highway bridge, Travis County, Texas

FORAMINIFERIDA

Reophax texana Cushman & Waters

ff-aplophragmoides calculus Cushman & Waters

H. excavatus Cushman & Waters

Ammobaculites coprolithiformis (Schwager)

A. texanus Cushman

Triplasia insignis (Plummer)

T. trilatera (Cushman)

T. trilatera plummerae (Sandidge)

Quinqueloculina antigua angusta Franke

Spiroplectammina semicomplanate (Carsey)

Trochammina diagonis (Carsey)

T. gyroides (-Cushman & Waters)

Bolivinopsis rosula (Ehrenberg)

Gaudryina rudita Sandidge

G. rugosa d'Orbigny

Plectina watersi Cushman

Dorothia bulleta (Carsey)

Nodosaria affinis Reuss

N. gracilitatis Cushman

N. manifesta Reuss

N. navarroana Cushman

Citharina multicostata (Cushman)

C. navarroana Cushman

C. webbervillensis (Carsey)

Dentalina angusticostata Cushman

D. basiplanata Cushman

D. communis d'Orbigny

D. crinita Plummer

D. elicatula Cushman

D. legumen (Reuss)

D. loreniana d'Orbigny

D. megalopolitana Reuss

Frondicularia clarki Bagg

Lagena acuticosta Reuss

L. hispida Reuss

Lenticulina navarroensis Plummer

L. taylorensis (Plummer)

Marginulina curvatum Cushman

M. navarroana Cushman

Neoflabellina reticulate (Reuss)

Planularia dissona (Plummer)

Saraceharia saratogana Howe & Wallace

Vaginulina cretacea Plummer

V. simondsi Carsey

Vaginulinopsis linearea (.Carsey)

Globulina lacrima Reuss

G. lacrima horrida Reuss

Goto: back to the Table of Contents, or on to the Field Trips

N. gracilitatis Cushman

N. manifesta Reuss

N. navarroana Cushman

Citharina multicostata (Cushman)

C. navarroana Cushman

C. webbervillensis (Carsey)

Dentalina angusticostata Cushman

D. basiplanata Cushman

D. communis d'Orbigny

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Guidebook to the Geology of Travis County

Austin's Earth Science Resources

Places to go for Help and Information

Diana Grunig and Egan Jones

This appendix lists most of the institutions and agencies that serve as sources of earth science information in Austin. Some of the listings will be of interest to those who want to learn more about the geology of Austin or of Texas; some will serve those who want to learn or teach basic geology or related sciences; others will only interest those who want specialized, advanced, or technical scientific information.

Information on locations and fees is correct as of August, 1977. (Check out their web-pages to find more current information)

MUSEUMS, EXHIBITS, COLLECTIONS

University of Texas at Austin, Campus

CAMPUS GROUNDS -- building and paving stones in many parts of the campus are rock from local and state quarries and from out of state. Many different rock types are represented; some of the sedimentary rocks show sedimentary structures.

WILL C. HOGG BUILDING -- decorative frieze around this building (the old Geology Building) depicts a variety of ancient life forms and crystal forms.

JACKSON GEOLOGICAL SCIENCES BUILDING- JGB -- retaining wall at west entrance contains a collection of large rock specimens and fossils; first and second floors inside the building contain exhibit and display cases.

TEXAS MEMORIAL MUSEUM -- (no admission charge); basement floor contains geologic exhibits, including mineral specimens and restored dinosaurs and other fossil vertebrates; outside of the building is an exhibit of dinosaur tracks.

BIOLOGY (PATTERSON) BUILDING -- **The Herbarium** contains pressed and dried samples of Texas native plants; inquire at the main office of the **Biology Department**.

HUMANITIES RESEARCH CENTER -- on the seventh floor are specimens from the Barron Collection on display. Ask to be let into the room.

J. J. PICKLE RESEARCH CAMPUS (formerly Balcones Research Center), Between MoPac (Loop 1) and Burnet at Braker Ln.

VERTEBRATE PALEONTOLOGY LABORATORY-- this lab is part of the Texas Memorial Museum and contains some formal exhibits and many fossil vertebrates in storage and under study.

INVERTEBRATE PALEONTOLOGY COLLECTION, Texas Memorial Museum -- contains most of the collections of invertebrate fossils at The University of Texas.

DEEP EDDY NATURAL SCIENCE CENTER, Deep Eddy Drive, just south of Lake Austin Boulevard -- The Science Center houses a museum with exhibits from many realms of the natural world, including geology. Geared primarily to children, admission is $.25 per adult and $.10 per child. The Center also sponsors classes for all age groups, some of which cover the basic earth science and related subjects.

TEXAS SYSTEM OF NATURAL LABORATORIES, Room 213, Littlefield Building (northeast corner, at 6th Street and Congress Avenue). -- The Texas System of Natural Laboratories serves as an intermediary between people engaged in serious scientific investigation and landowners all over the state who have agreed to permit their lands to be used as natural laboratories in scientific research projects.

NATURAL CAVERNS AND **STATE PARKS** -- A wealth of different geologic environments lies within an easy day's outing from Austin. Many of them have interesting outcrops and fossil localities within their boundaries, and even those principally of historic interest provide a chance to view the geology on the way. Any good Texas road map will show exact locations; a publication by the Bureau of Economic Geology, Geologic and Historical Guide to the State Parks of Texas (Guidebook 10) summarizes the geology of each park. Information about fees and facilities can be obtained from the Texas Parks and Wildlife Department.

LIBRARIES

University of Texas at Austin

Geology Library -- third floor, Geology Building; extensive collections on geologic literature and maps; holdings are open stack and available for room use to anyone and may be checked out with a library card, which is free to UT students and staff, and available for $2 plus a $15 deposit to others (apply at Main Desk, **Perry-Castaneda Library**).

Architecture Library (Arch. Bldg.) -- includes land use and city planning materials

Barker Texas History -- contains Texas materials, especially historical, including maps

Life-Sciences Library (Main Bldg.)

Chemistry (Welch Bldg.)

Engineering (Taylor Hall)

Latin American Collection (Sid Richardson Bldg.)

Tarlton Law Library (Townes Hall)

Physics-Mathematics-Astronomy (R.L. Moore Hall)

Perry-Castaneda Library -- this is the University's main library. The facility houses the collections of the old Main Library (formerly located in the UT Tower) and several branch libraries including Business Administration, Economics, Classics, and Education-Psychology. Its collections cover all the social sciences and humanities as well as general and interdisciplinary areas of knowledge. The library contains the card catalogue for the entire holdings of the UT Library System.

Visual Instruction Bureau -- Education Annex, north of the Texas Olympic Swimming Center on San Jacinto. The Bureau holds a collection of films, some with earth science content, which can be rented.

Texas State Library and Archives -- Directly east of the Texas State Capitol Building, on the northwest corner of 12th and San Jacinto Streets; contains reference works about Texas and old records and other documents of the state. Open to the public, check-out privilege limited to state employees.

Austin Public Library -- Main Library is at 401 West 9th Street, inquire here for branch locations and bookmobile schedule; geologic holdings are small and almost entirely non-technical; the Main Library houses the Austin-Travis County Collection, which contains books, manuscripts, reports, and photographs from and about the Austin area.

St. Edwards University -- Library Building, St. Edwards' Campus is in south Austin and bounded by I.H. 35, Woodward Street, South Congress Avenue, and St. Edwards Drive; the library is open stack and contains a small collection of basic geology books.

See all PROFESSIONAL SCIENTIFIC ORGANIZATIONS with libraries which may be of use.

PROFESSIONAL SCIENTIFIC ORGANIZATIONS

Bureau of Economic Geology (Pickle Research Campus) -- The Bureau serves as the state geological survey for Texas. Public services include: publications available for sale, covering many aspects of Texas geology, technical and non-technical -- including geologic maps, guidebooks to state and federal parks and to areas of particular geologic interest; maintenance of a reading room containing publications about Texas geology, including rock identification; lectures to public groups. Inquiries may be made at the reception desk, 5th floor, Geology Building, or addressed to:

Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, TX 78712

United States Geological Survey, (Out on Cameron Rd. North of 183) -- The United States Geological Survey maintains an office of Water Resources Division, which handles water data and investigations for the state of Texas, and a branch office of the Office of Energy Resources, Geologic Division, which deals with south Texas uranium, in this building. The water Resources Division library contains publications from the other divisions of the U.S.G.S., too. Inquire at the information desk, Room 649.

General Land Office (Stephen F. Austin Building, 17th and Congress) -- This is a state agency that holds information on the original titles of privately owned land, and handles all state-owned land. Inquiries about state-owned mineral resources or coastal lands could be directed here, either to Energy Resources Management, Room 849, or Land Resources Management, Room 749.

Texas Water Development Board (Stephen F. Austin Building, 18th and Congress) -- This state agency manages the ground and surface water resources for Texas and maintains a library of relevant literature and a map library. Information: Room 513.

Texas Water Quality Board, (Stephen F. Austin Building, 18th and Congress, 4th Floor) -- Records of water quality measurements and investigations are handled by this state agency.

Texas Highway Department, District 13 Headquarters, (I.H. 35, north of its junction with U.S. 183) -- The Highway Department has county maps showing all the roads in a county, has some aerial photographs of Texas, and publishes county reports, some of which contain geologic discussion and geologic maps.

Texas Parks and Wildlife Department, John H. Reagan State Office Building (SW corner of 15th and Congress) -- This department has information on Texas flora and fauna and ecological studies, particularly for areas such as the Texas coast. The information desk and publications sales office are on the first floor.

Planning Department, City of Austin, (124 West 8th Street) -- This city department has large-scale plate maps and aerial photographs, from the 1940's and the 1960's for much of Austin, and they will sell copies.

National Weather Service, (main Terminal Building, Robert Mueller Airport, East on Manor Road) -- This station receives current regional and national weather reports, collects local weather data, and stores weather data for the Austin station from the present back to the station's opening.

Guidebook to the Geology of Travis County

Field Trip No. 1: Shoal Creek, Austin, Texas

TO THE TEACHER AND/OR FIELD TRIP LEADER

This field trip is designed to be a two to two and one-half hour field event followed up with a "post lab" classroom discussion and/or evaluation session. Your students will learn more from this trek if you "pre lab" the section**, students' introduction**, concentrating particularly on the terms listed and concepts relating to the terms. The **students' introduction** also has an assortment of suggested questions designed to "cue" your students to look for certain aspects or relationships that could be overlooked by making the field trip a "show and tell" experience. Conditions do get hectic and hurried on a field trip, especially with eighth graders; therefore, the better prepared your students are beforehand, the more they will see and remember afterward.

Two additional points:

Although a "sketch map" is provided for tour routing and suggested stopping points, several of these points offer limited parking for an auto caravan or a large bus. You should survey the route beforehand to determine which points will provide the best learning experiences for your students.

Wooten Park **(Stop #6)** has plenty of sights to offer, including a neat place to break for picnic lunches.

STUDENTS' INTRODUCTION

The Shoal Creek field trip is your opportunity to examine an urbanized creek from its headwaters to its end at Town Lake. When you complete the tour, you will have a good idea of the changes man makes on a creek when he builds homes, roads, streets, and bridges in the creek watershed. A **Glossary** of terms and a **list of suggested questions** are provided to refresh your memory on certain features of landform. Please refer to the questions on this page and to the **Glossary** found on the back pages.

When you complete this tour, you should be able to explain in your own words the answers to the following:

1. List three or more activities of man that have made Shoal Creek more likely to flood than when it is in its natural state.

2. The natural springs at the headwaters of Shoal Creek are almost dried up. Can you think of some reasons for this?

3. What effect has "urbanization" had on:
a. the speed of water runoff?
b. stream bed sedimentation?
c. soil stability?

4. What do you think should (and should not) be built on Shoal Creek's flood plain?

5. What could be done to make Shoal Creek a safer part of Austin?

6. What are the advantages and disadvantages of making Shoal Creek a "storm drain channel"?

7. Would Austin have any problems installing storm sewers to take the runoff load from Shoal Creek? List your ideas on these problems.

8. Would deepening the creek in flood prone areas solve the problem? Explain your answer.

9. What causes the green slime in pools and slow-moving areas of the creek? (Note: most natural streams have little or no slime).

10. List all of the types and locations of stream pollution you noted during the field trip.

11. The City of Austin has built the main sewer lines along the creeks whenever possible. Can you give at least one advantage and one disadvantage of this practice?

Brief History of the Shoal Creek Area and Austin

Not very long ago in geoloaic time, Austin was part of a huge inland sea which stretched from Texas to parts of Illinois, Idaho, and the Dakotas. The very land you are standing on was at times as much as 100 meters (300 feet) or more below the surface of the water! Yet, there were also times when the waters were shallow and dinosaurs waded around in our region. Pilot Knob, an ancient volcano off the Locl, hart Highway south of Bergstrom Air Base, rose above the sea, belching smoke, ash, and lava. Actual beaches formed around this volcano (which later became inactive) and looked from the air like one of the many volcanic islands (called atolls) remaining in the Pacific Ocean today.

The land was not still in that time, nor is it still todav. High land is worn low and flat, and old flat land is raised upward to form new hills or mountains. Austin is now what was once the bottom of the sea. What we are concerned with is what happens to this sea floor when it becomes high ground and when wind, rain, and man begin to work on it.

To really understand how a creek "operates", you must understand that it takes a lot of land to shed enough water to get a stream going in the lowest parts of the area. When it rains, a part evaporates and returns to the air. The remainder, which flows downhill on the surface of the ground via small gullies, or via city storm drains, is the main water supply or the stream. If there is enough water, the stream will travel toward lower points, often joining other streams until it gets to the lowest point possible -- a lake or the ocean. Often, during very dry weather, a stream will not have enough water coming in from its watershed, and it will become a dry, rock stream bottom. During periods when a great quantity of rain falls, the stream will rise and swell with swiftly moving quantities of water just like a medium-sized river. And when it really rains -- well, you will see what this can cause during your trip.

THE TOUR

STOP #1

North access road to U.S. 183 on the east side of the Missouri-Pacific Railroad watering stop.

The scene facing north is the headwaters of origin of Shoal Creek. This field of tall grasses and few trees doesn't look like much, but the waters begin to move downstream from this field and from the Balcones uplift to your left.

Once, there were welling springs in the field area. Steam locomotives of the Missouri Pacific drew their water supply from these natural springs. A few of the springs still produce surface water, but as you can see, the water either evaporates or is absorbed by the ground before it can get to where you are standing. Of course, if it has rained enough recently, you should see some water running by your position.

Why do you suppose there would be springs in and near Austin? Can you think of other natural springs in and near Austin? It just so happens that these springs follow all along the Balcones fault from north of Dallas to south and east of San Antonio. A natural underground aquifer or "waterpipe" was broken by the uplift or fracture along the Balcones Escarpment many years ago, and the waters found their way to the surface by following the fault upward.

You will notice that the high ground to the left, the Balcones Uplift, is covered with trees, but the field ahead and to the right of your position is mostly covered with grass and shrubs. This points out that there is a difference in soils and the rock underlying those soils between the highland and the adjoining lower land.

STOP #2

Proceed from the access road to Shoal Creek Boulevard (across and south of Hwy. 183).

You will notice the sudden widening and deepening of the creek. This area is on the normal creek flood plain, so the creek was straightened, widened, and deepened to handle the immense rush of water draining off the highway and adjoining commercial buildings and large paved parking lots whenever the rains are intense. A good rain will fill this canal to the point of overflowing in less than two hours, although the water moves downstream very rapidly. Can you imagine how much water that is? If you look along the banks, you will see several large, concrete pipes jutting out into the creek from the banks. Some of these pipes are over three feet in diameter. They are storm drains which collect water from your streets and carry it underground until it comes out somewhere along a stream or creek. These drains really move the water efficiently and quickly, and seldom does a street or lawn fill with water even in the heaviest rain. The trouble is that the poor creek gets all that water so fast and so heavy that sometimes the creek can't handle it and flooding results.

What effects do these storm drains have on Shoal Creek besides flooding? Do you see any effects of the storm drain on the opposite bank -- any signs of erosion? -if not, keep the storm drains in mind as we proceed downstream.

STOP #3

Spicewood Springs Road and Shoal Creek

This small tributary stream is one of the first natural "feeders" into Shoal Creek. Notice the deep dip in the road (Shoal Creek Boulevard) to allow flood waters to flow over the road. It was very near here that a motorcyclist was drowned in June 1972. Can you see why? Now go to the bridge and just look around. The underpass of this bridge is much too small for the amount of water now pouring past this point during flooding. When the bridge was built some years ago, this passage probably was able to handle the stream flow. Now, the water simply backs up until it can rise over the bridge! Look at the guard posts being undercut by this overflow. Now note the stone pillar across the street by the apartment. Check the erosion on the roadback. This is a very dangerous area to be in during a heavy rainstorm.

STOP #4

Return to Shoal Creek Boulevard and turn left (south) -- arrive at Northwest Park.

Enroute to Stop #4 you no doubt noticed that there are many nice homes along the creek. Almost all of these homes are located on the creek floodplain. Several of them have experienced frequent flooding. This park (northwest corner) marks the spot where the deepening and widening of Shoal Creek ends. From here on downstream to Wooten Park, the narrow, meandering Shoal Creek occupies its natural bed. When all of the rushing water gets to this point, the narrow banks, trees, and rushes slow the stream down, and cause it to spread over lawns and homes that are within your view.

STOP #5

Return to Shoal Creek Boulevard via Alberta and Daugherty and Greenlawn, retracing the route from the Boulevard. Shoal Creek Boulevard at Hunt Terrace.

This is the area which experiences flooding every three to five years. You can imagine that as upstream development continues, the flooding here will become more severe and more frequent. If we could plan the use of this area all over again, what do you think we should do with it?

ENROUTE TO STOP #6

Northland and Shoal Creek

The road engineers wanted to put in the less expensive shorter bridge, so they narrowed the banks at this point. Looking upstream, you can notice the shallow banks where the backed-up waters flood.

Hancock Drive and Shoal Creek

This bridge was designed to handle the original 10 year flood calculation (before urbanization), but it is now completely inadequate and, therefore, frequently floods.

45th Street

Downstream, the creek channel is naturally deep and is not flood-prone except for the west bank housing area which is too close to the channel.

STOP #6 - WOOTEN PARK

You are looking at what could be called a river channel in some places. Upstream, urbanizatiion has increased the water flow so much that Shoal Creek is downcutting about two inches a year at this point. Those hugecobbles were rolled down from the Shoal Creek Hospital and Medical Tower construction sites upstream. A few of the larger ones probably weigh nearly 1000 pounds. Can you imagine the water force needed to move them? What would such a force do to a brick house? Have you bothered to keep a count of the number of storm drains you have seen since we began the tour?

LUNCH BREAK!

This is normally the conclusion of the tour except for small groups, since further points downstream are in very congested areas. Parking is available at the Municipal Power Building, and your group could find an interesting terminal view of Shoal Creek as it empties into Town Lake.

OPTIONAL STOP #7

Drive south on Lamar Street and turn left at 5th Street. There is limited parking space just west of the bridge over Shoal Creek on the right (by a used car dealer).

If your group is small and manageable, you might let them follow the creek to the north side of the power plant (West Street and First) where you can pick them up. This mini-hike will be self-explanatory for the following features:

1. Several severe slumps and/or bank failures.

2. Severe erosion at 90 degree right turn in the stream at Third Street area.

3. Raw effluents entering the stream from both a large storm drain and from an area very close to the power plant.

Although you have made several stops during the last two or three hours, there should be many things which stand out in your mind as being changes caused by man. As you return to your classroom or home, take a pencil or pen and a sheet of paper. Together with a friend, make up a list of all the things you can remember that man has done to Shoal Creek to change its natural condition.

MAP 7-150K

On to Field Trip #2... change its natural condition.

MAP 7-150K

Guidebook to the Geology of Travis County

Field Trip No.2: Balcones Fault Zone

Mount Bonnell, Zilker Park, Highland Park Elementary School

TO THE TEACHER AND / OR FIELD TRIP LEADER

The Balcones Field Trip consists of three stops: Zilker Park, Mt. Bonnell, and Highland Park Elementary School. None of these three gives a clear, concise view of the Balcones Escarpment alone, but each presents one or more aspects of this huge fault. The tilted and folded outcrops exposed at Highland Park School are an old rock quarry now filled in for a new use as an athletic field in the school recreational-park complex. Mt. Bonnell is a very scenic, dramatic bastion created by the Colorado River carving a deep valley through the Balcones. Zilker Park is the site of natural springs. Many of these springs are located along the Balcones Escarpment.

All three stops have adequate parking for a school bus, and there is no preferred sequence of stops. Your sequence depends upon your initial location; however, Zilker might be the best choice for the third stop since it offers the best facilities for a luncheon break and recreation.

There are a few competencies that your students will need to have to maximize their learning:

1. Bedding - originally deposited horizontally.

2. Law of Superposition - youngest layers on top, etc.

3. Accretion - how our coastal regions and the continental shelves are thought to have been formed.

4. Graben - what it is, and how it is formed.

5. How the forces of stress, tension, and shear act upon rock.

6. The definitions of aquifer and water table so that students will know the mechanics of a spring.

The actual length of time for this field trip obviously will vary from one schoolls location to the other. Also, it is dependent upon how long you wish to dwell in any one location. To give you an idea of timing, thirty minutes at the Highland Park School is ample to view the outcrops; longer stays might interfere with the schoolls playground activities. At Mt. Bonnell, the time could range from 30 to 45 minutes. If your group is 8th grade Earth Sciences, then 30 minutes is more than enough time; but an 11th or 12th grade Geology class might want to look in more detail at the topography and the stratigraphy of the rocks. Zilker is a 30 minute tour (without lunch or recreation). The entire trip, from departure to return to school could be accomplished from most Austin locations in a little over three hours.

STUDENTS' INTRODUCTION

You are fortunate to live in Austin, which has many varied and dramatic geological points of interest within its city limits. Our Balcones field trip will concentrate on the few, but very good, exposures we have of the ancient fault we call the Balcones Escarpment. We will have only three stops: Zilker Park, Mt. Bonnell, and Highland Park Elementary School.

The purpose of this tour is to give you an opportunity to learn how a fault occurs, what a fault looks like, and where you can find one. When you complete your tour, you should be able to answer the following list of study exercises:

1. Why is the hill country, just west of Austin, so different from Austin and eastward?

2. List at least three prominent land features that identify the boundary of the Balcones Escarpment.

3. Draw one or more possible results of a rock mass failing under (1) stress by the force of Tension, and under (2) stress by force of Compression.

4. Why are so many Central Texas cities located along the fault zone?

5. Explain the nature of the force that most likely caused the Balcones Escarpment.

A VERY BRIEF HISTORY OF THE BALCONES ESCARPMENT

Not very long ago in geologic time (only a mere 300 million years ago, more or less) our Texas coast did not quite make it to Beaumont, Galveston, Corpus Christi, Brownsville, etc. Take a look at your Texas map **(Fig. 54)**. You will note that both the present coast and the fault zone are heavily outlined. This inland fault approximates very closely the existing coastline during the Permian period. All of the good Texas land from that line to our present coastline (well over 100 miles Gulfward from the ancient coastline) has been added from rocks, sand, and muds washed down from the hill country and carried by the many rivers like our Colorado River. You can easily imagine that it has required an immense amount of silt and all of those millions of years for nature to pile up enough material to make Texas the huge state that it is today. So when you consider Texas' size, think about all the erosion and piling of materials that make it!

When material is piled on other material, the result is that the whole pile tends to sink, as great weights drive out water and causes the material to compact **(Fig. 55a)**. As this great mass slowly sank, it caused tension, or pulling effect, whose force was strongest along the ancient continental border or coastline. One day (still millions of years ago), the stress became great enough to overcome the strength of the rocks, and a gigantic shear occurred along the original coast. A huge graben was formed in an area located against the Permian coastal region and our Balcones Escarpment was born **(Fig. 55b)**.

The original relief of this graben was much greater than it is today. Erosion has worn down the high part, or the hill country, and the deep trench has been filled in considerably with sediments from the hill country **(Fig. 55c)**. When you climb Mt. Bonnell and look at the countryside, you will find that there is still plenty of relief remaining.

There is no large scale faulting occurring in Texas today like that which resulted in the Balcones Escarpment. However, along the entire Louisiana and Texas Gulf coast, a whole series of small slumps and earth movements occur daily somewhere! These movements are of particular concern to city engineers in Houston, and the annual damage to buildings, streets, and underground utilities is very costly.

THE TOUR

Zilker Park

There are more than four distinct points of interest at Zilker Park (excluding the refreshment stand). As you enter the park, you will notice two stone columns at the entrance of the parking lot. These "gates" are made of a sample of every rock-type native to Texas. How many of these rocks can you identify? You should be able to name at least eight.

Zilker Park contains some of the many natural springs which are located along the Balcones Escarpment. Natural artesian waters rise to the surface along a fault or break in the earth's crust and are supplied by underground water that is stored in an aquifer. These springs supply water to the swimming area, and also add to the water flow of the Colorado River. San Marcos, which is only 30 miles south of here, also has many large natural springs. In fact, many of the early towns in central Texas were located where natural springs existed. The nearby historical marker will provide you with some data on the amount of water produced by Barton Springs. **Figure 56** shows the relationship between the aquifer and the artesian waters at Barton Springs.

As you are looking down into the springs, you are standing on some rather unusual flagstones. Look at them and see -Lf you can think of anything else that might look like this. Any ideas? These flagstones are like fossils, but instead of being remains of once-living creatures, they are a fixed record of an event. Have you ever noticed how an old mud puddle tends to crack into a definite pattern as it dries out? Now look again at these flagstones. Do you see the similarity? Now turn back to the mud hole with cracks -- what happens to the cracks when it rains again? These ancient mud cracks are not swollen-out and smoothedover again. If you were a geologist studying these rocks, could you assume that the story locked up in these cracks is that there was a very long dry spell and a large pond or lake, or even a sea, dried up? You can now see how geologists reconstruct events which happened very long ago in time.

The great forces which produced the Balcones Escarpment broke solid rock, shoved some land up, and caused other land parts to fall. If you will now look at the pool toward the upstream or dam portion, you will notice several very prominent and long cracks or faults. You probably have seen faults before on highway banks where the roadway cut into solid rock. Although the Balcones Fault is thought to be one very long fracture, the fact is that nature doesn't do things so neatly. Almost every exposed rock formation in our area shows these kinds of cracks, faults, and fissures to tell us that almost all rock formations near the Balcones Escarpment were under the same great force.

Mt. Bonnell

This point is at a divide. Upstream of the Colorado is the hill country which is the higher, or uplifted, section from the Balcones. Downstream, you will also notice that the land soon flattens out. Also, note the change in the tree cover and the species of trees. You are standing in hill country, and it is full of cedar, youpon, and flowering bushes. Look now at the flatlands and you will see fewer trees, almost none of which are cedar. This point is only a little over 750 feet above sea level, but the soil and the climate are sufficiently different from the flats to make a difference in rainfall and in the types of vegetation.

The rock layers all along Mr. Bonnell and vicinity are horizontal (coming up to Mt. Bonnell it seemed that the layers were slanted, but this is an illusion caused by the incline of the road). This means that this part of the Balcones is the uplifted part. The portion of the graben which dropped shows tilted bedding and lots of fractures.

How long do you think it took for the Colorado River to carve its gentle slope through this hilly area? Do you think there might have been a time when this meandering river might have formed a falls like Niagara Falls at this point? Later, might there have been foaming rapids as the Colorado went over the Balcones?

Highland Park Elementary School

This park was a rock quarry, and the lower field next to all of the exposed rock is a fill. This is proof that an old quarry need not be an ugly, water-filled hazard to the neighborhood.

Look first at the solitary rock exposure nearest the tennis courts. If you look closely at the angle, you will see that it slants. Look closely at the rock surface facing the school. You can see long striations caused by rock scraping against rock as this piece probably moved upward at a slant.

Looking downhill at the field and the rock wall beyond, you can see the slanting layers. This is the downdropped portion, or the graben, since the layers usually tilt at the edges of the graben.

Walk around to get a closer view of the outcrops; you will notice many fractures and faults along the field.

The actual location of the Balcones fault plain is not easy to spot since it is well covered, but it is approximately along a line parallel with Balcones Drive and the first row of houses across the street. Balcones Drive does follow the fault very closely in this area.

Glossary of Technical Terms

A

Agglutinated	- refers to those foraminiferans of which which the tests are composed Of minute pieces of substrate or other material cemented by an animal secretion.
Aquiclude	- a formation so impermeable that it will not transmit enough water for a well or a spring.
Aquifer	- a permeable layer of rock under the surface of the ground through which water can move. Usually, aquifers are sand-stone or limestone, but some may be mixed sand and gravel, or even fractured rock. Claystones, shales, and most igneous and metamorphic rocks are aquicludes.
Artesian water	- water that is under pressure, naturally. When tapped by a well (or spring) it isable to flow upward. If it flows to the surface it is flowing artesian.

B

Basanite	- an extrusive rock composed of calcic plagioclase and iron-magnesium silicates (augite and/or olivine), and a feld-spathoid (nepheline, leucite, or analcime).
Biolithite	- limestone that is bound together by a framework of shells of organisms; a boundstone; reef rock that is held together by an organic framework.
Biomicrite	- a limestone consisting of a variable proportion of fossil skeletal debris contained in a carbonate mud; when used, the major organism should be specified: crinoid biomicrite.
Biosparite	- a sparite, (see same), containing fragments of,the shells of fossils.
Bivalve	- a common term for the pelecypods (see same).

C

Calcarenite	- a sandstone composed of cemented, sandsize grains of calcium carbonate.
Carbonate	- salt of carbonic acid; a compound containing the C03 radical; in most uses carbonate refers to calcium carbonate -CaCO3-
Clastic	- consisting of fragments of rocks or of the hard parts of organisms.
Creep	- the almost imperceptibly slow movement of soil and surface debris down the slope propelled by gravity.

D

Disconformity	- a buried surface of erosion that represents in succession (1) deposition of strata, (2) erosion of some of the strata, and (3) deposition of additional strata.

F

Fault	- a break in the earth's crust accompanied by a displacement of one side of the fracture with respect to the other, and in a direction parallel to the fracture; the fracture does not have to be straight.
Floodplain	- that part of a stream valley that is covered with water when the river or stream overflows its banks; it is usually that part of the even valley floor that has been formed under the present regime.
Flood-stage	- any part of the floodplain that is covered by floodwater for any designated description; usually in terms of return to that magnitude again, as in 20-year, 40-year, or 100-year flood.
Fold	- a bend, flexure, or wrinkle in rock strata, which was produced when the rock was bent by internal earth forces.
Foraminiferan	- an individual of the order Foraminifera (Class Sarcodina); one of many small, unicellular animals with a protective test of harder calcium carbonate or agglutinate.

G

Geosyncline	- a large linear trough that received stratified sediments for a long period of time, subsiding slowly enough that the sediments were usually terrestrial or deposited in relatively shallow water.
Glauconite	- a green mineral commonly occurring in sedimentary rocks; it is a hydrous potassium iron silicate that is closely related to micas and clay minerals.
Graben	- a depressed segment of the earth's crust bounded on at least two sides by faults.
Gradient	- the slope of a streambed, measured in feet per mile or meters per kilometer.
Grainstone	- a limestone in which there is no mud and in which the allochems (usually shell fragments or oolites) are in contact and are self-supporting; a biosparite.

I

Inert gas	- one of any of those gases in the zero group of the periodic table; its outer electron shell is saturated and it does not actively participate in chemical reactions. Inert gases included helium, neon, argon, krypton, xenon, and radon.
Intertidal-	- used to describe that area between high and low tide (sometimes including stor-Tr. tides) and the sediments deposited in that area and the rocks resulting from those sediments.
Isotopic	- an adjective referring to Isotopes; i-sotopes are elements having an identical number of protons in their nuclei, but differing in the number of electrons as oxygen-16 vs Oxygen-18.

L

Lava	- the molten silicates or the congealed rock that issues onto the surface of the earth.

M

Mafic	- refers to rocks or magmas that are formed largely of iron and magnesium silicates.
Magma	- naturally occurring fluid that congeals to form rock, either within the earth or upon the surface of the earth.
Mantle	- the earth is composed of three layers. This is the layer of the earth's interior between the core and the crust.
Melilite	- a group of minerals containing (sodium or calcium) plus (magnesium or aluminum) plus silicates.
Metamorphism	- the process of altering rock by pressure and/or heat; alteration may be in texture, composition, or internal structure of the constituent minerals to produce new minerals.
Micrite	- a limestone composed of clay-sized fragments; a claystone of calcium carbonate; mudstone.
Mollusk	- one of the animals belonging to the Phylum Mollusca, which includes cephalopods, gastropods (including snails), pelecypods (bivalves), and some smaller groups.
Mudflow	- a flow of heterogeneous debris or sediment lubricated by a large amount of water.

N

Nepheline	- a mineral composed of (sodium or potassium) aluminum silicate.

O

Olivine	- a greenish, translucent mineral series composed of varying amounts of magnesium silicate and iron silicate.
Oolite	- a spherical or ellipsoid body, less than 2 mm in diameter, that has concentric internal structure.
Outcrop	- an outcrop is any appearance of rock at the surface of the earth.

P

Packstone	- a packstone is a limestone composed of grains with the intervening spaces filled with mud; a packed biomicrite.
Pelecypod	- a bivalve; a member of the Mollusca in which the hard parts are composed of two sections fitting together to enclose a space that contains the soft parts of the organism.
Permeability	- the degree or rate at which a liquid will pass through rock or other earth material.
Phenocryst	- one of the large, conspicuous crystals of a mineral in a rock, which because of its greater size is set off from the rest of the rock.
Plagioclase	- the name for a series of minerals ranging from sodium aluminum silicate through various combinations of sodium and calcium silicate to calcium silicate.

Plastic	- any permanent change in shape or volume deformation that does not include failure by rupture; and that, once started, continues without increase in the deforming force.
Pyroclastic	- rock that is formed of detrital volcanic material deposited as sediment from air or water.
Pyroxene	- one of a number of minerals composed of (magnesium, iron, calcium, sodium) plus (magnesium and/or iron or aluminum) silicate.

R

Relief	- the general difference in elevation between the highest and lowest parts of an area.
Runoff	- the amount of water discharged through surface streams.

S

Sabkah	- an area of deposition of salt in surface or near-surface sediments.
Sediment	-a solid material in suspension in air or water; the material that has settled out of such a suspension.
Septarian	- a roughly rounded concretion cut into sections by cracks that have later been filled with some mineral.
Shear	- a cutting or breaking of a solid body such as a rock by adjacent forces acting in opposite directions.
Shrink-swell	- refers to those clays or soils that clay alternately expand when wetted and shrink when dried.
Slickensides	- polished grooves on a fault surface resulting from abrasion along the fault plane.
Slump	- (1) material that has slid down a slope; (2) the en masse movement of such material.
Soil	- rock material that has been altered by physical, chemical, and biological agents to produce a medium that will support plant life.
Sparite	- a limestone composed of grains without mud, but cemented with calcite.
Spinel	- a mafic rock without plagioclase and peridotite containing spinel, a (magnesium-iron) aluminum silicate material.
Spring	- a place where the water table reaches the surface and water flows more or less continuously.
Stability	- in reference to soil or rock, stability refers to those that do not easily move downslope when saturated with water or shook by earthquakes.
Storm sewer	- an open or enclosed conduit to rapidly remove surface runoff from rains or melting snows; most carry the runoff to the nearest natural draw, gully, or creek.
Strain	- the change of dimensions of matter in response to stress.
Striation	- a scratch or small groove caused by movement along a fault.

Strength	- (of rocks) is the stress at which rupture occurs or plastic deformation begins.
Stress	- a force applied to a material that tends to change the dimensions of the material.
Subtidal	- refers to the area below low tide or to sediments deposited in that area.
Supertidal	- refers to that area above the tidal range, or to sediments deposited in that area. Such sediments are usually storm deposits, if limestone, or reworked storm deposits, or deposits resulting from evaporation of water.

T

Tension	- a system of forces tending to draw apart the parts of a body. Opposite of compression.
Trap-rock	- a non-technical term that frequently refers to any dark colored rock intersecting other rock.

U

Ultramafic	- an igneous rock containing no quartz or feldspar and less than 45% silica.
Underground	- groundwater; the water that is confined in the rocks beneath the soil.

V

Volcanic ash	- pyroclastic sediment with fragments of less than 4 mm in diameter.

W

Wackestone	- in limestone composed of mud, but also continaing grains scattered through the mud; a biomicrite.
Water table	- the upper surface of the zone that is continually and completely filled with underground water, except where that surface is formed by an impermeable stratum.

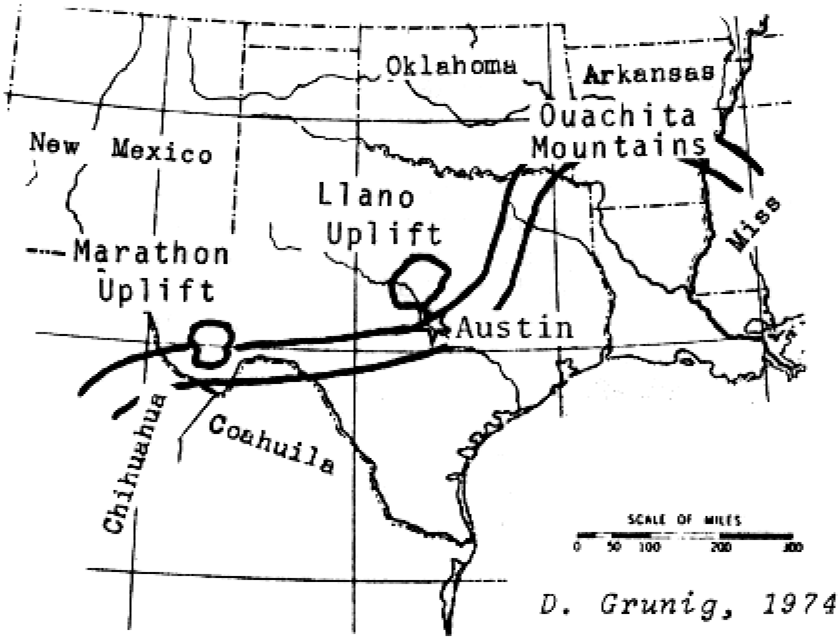


FIGURE 1
Location of Ouachita Structural Belt

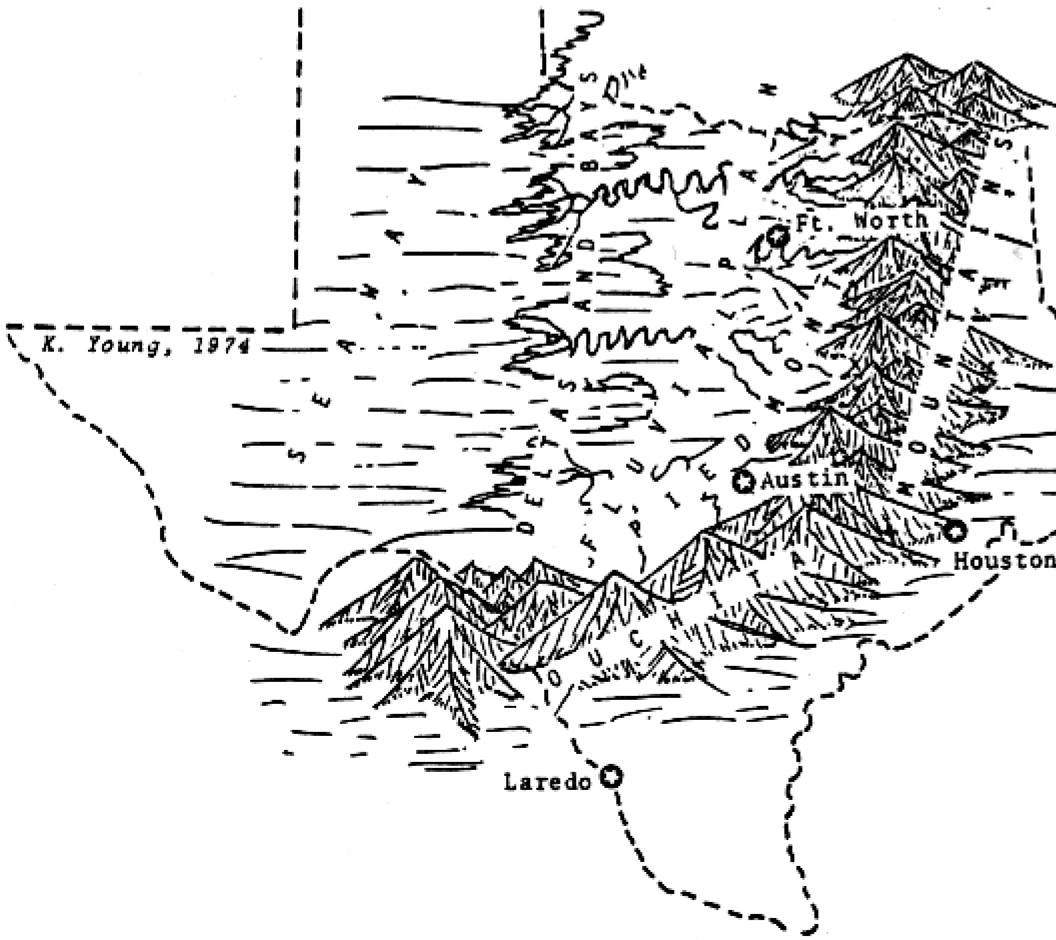


FIGURE 2
Central Texas in the Upper Pennsylvanian

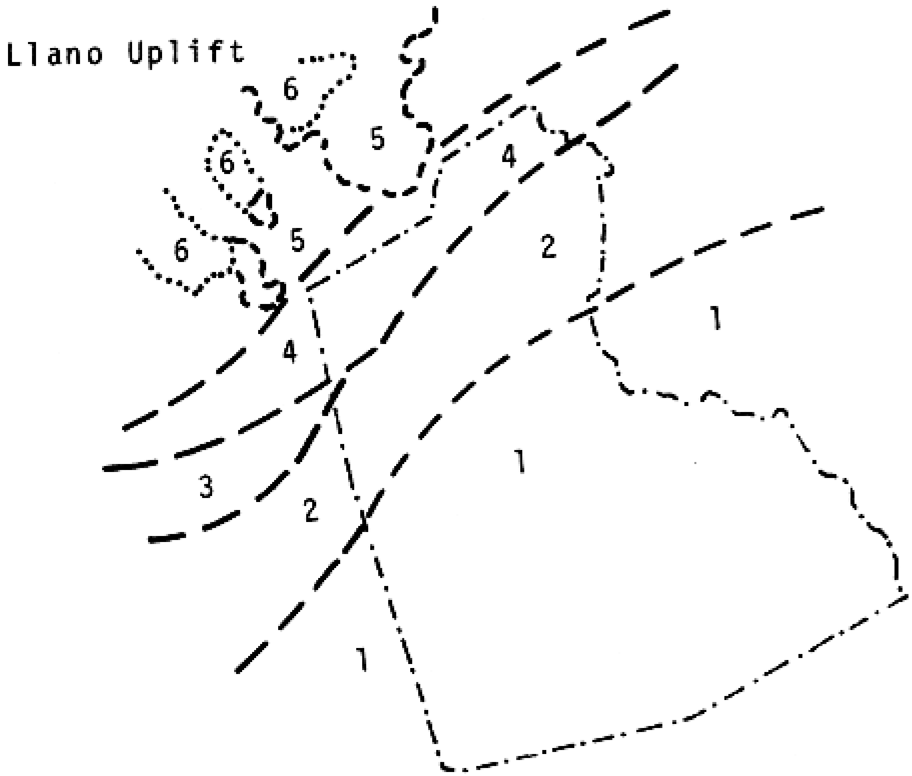


FIG. 3
PALEOZOIC ROCKS,
AUSTIN AREA

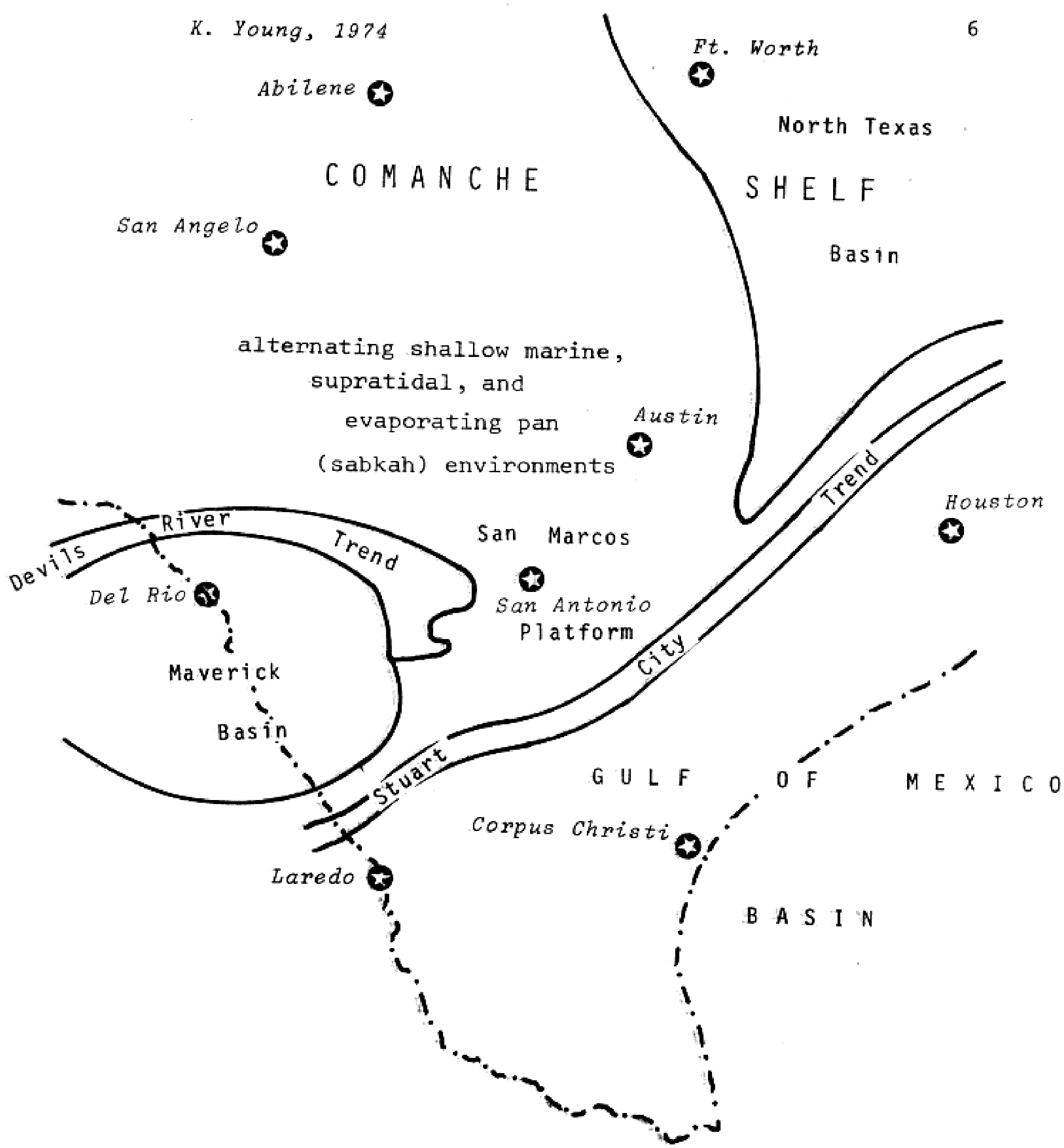


FIG. 4
CENTRAL TEXAS
IN THE LOWER CRETACEOUS

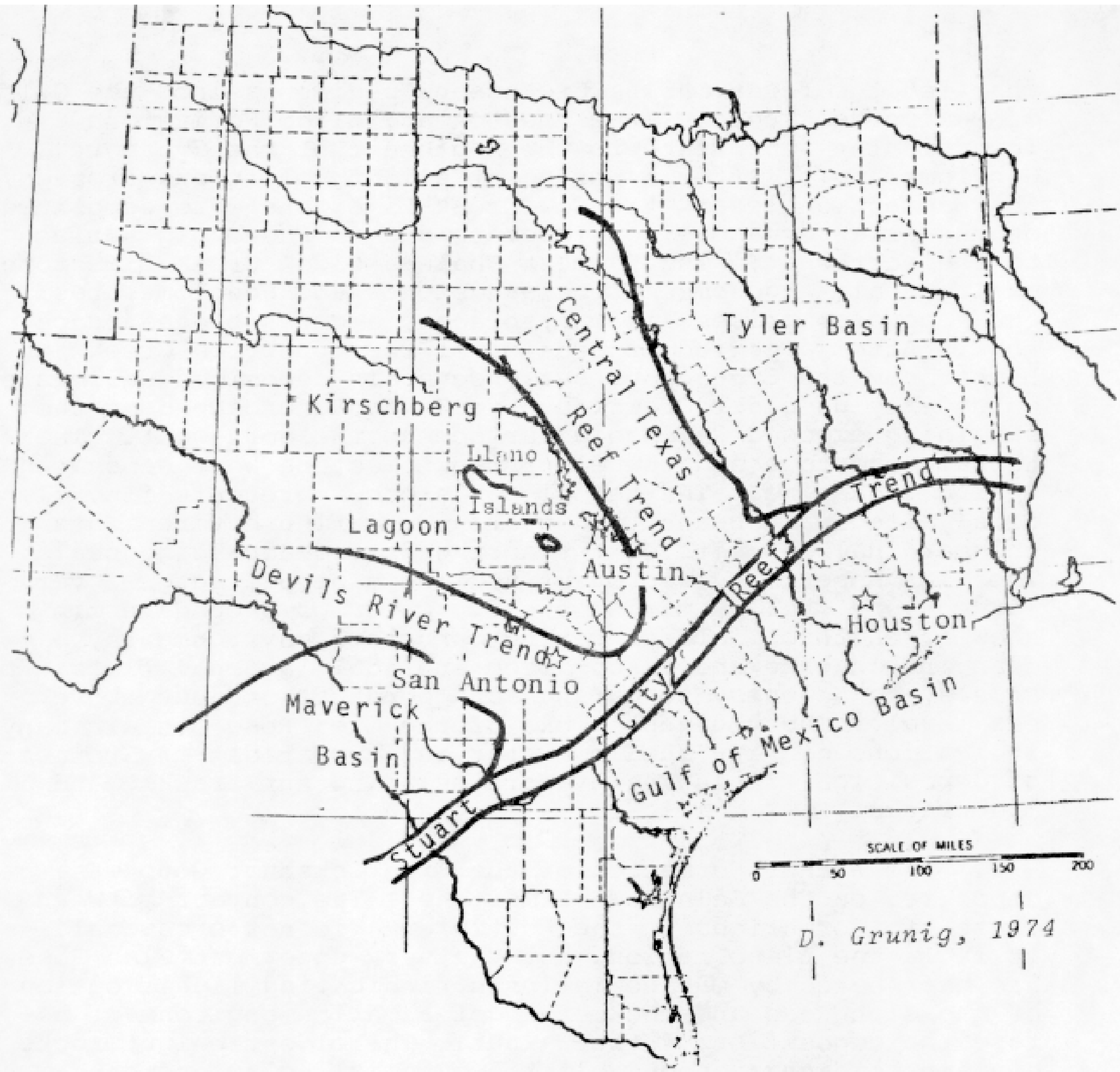


FIG. 5

EDWARDS PALEOGEOGRAPHY, CENTRAL TEXAS

(MODIFIED FROM FISHER AND RODDA, 1969)

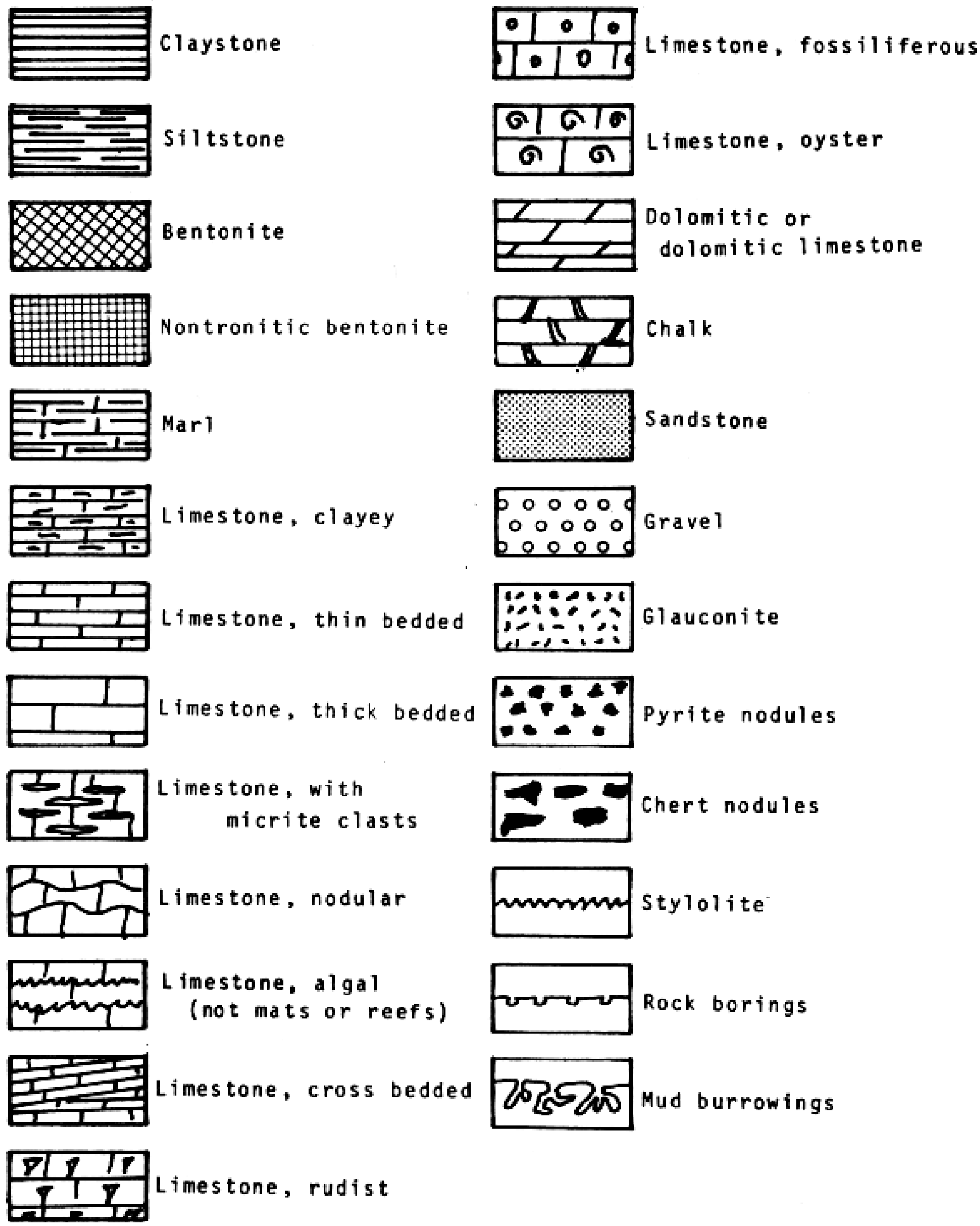
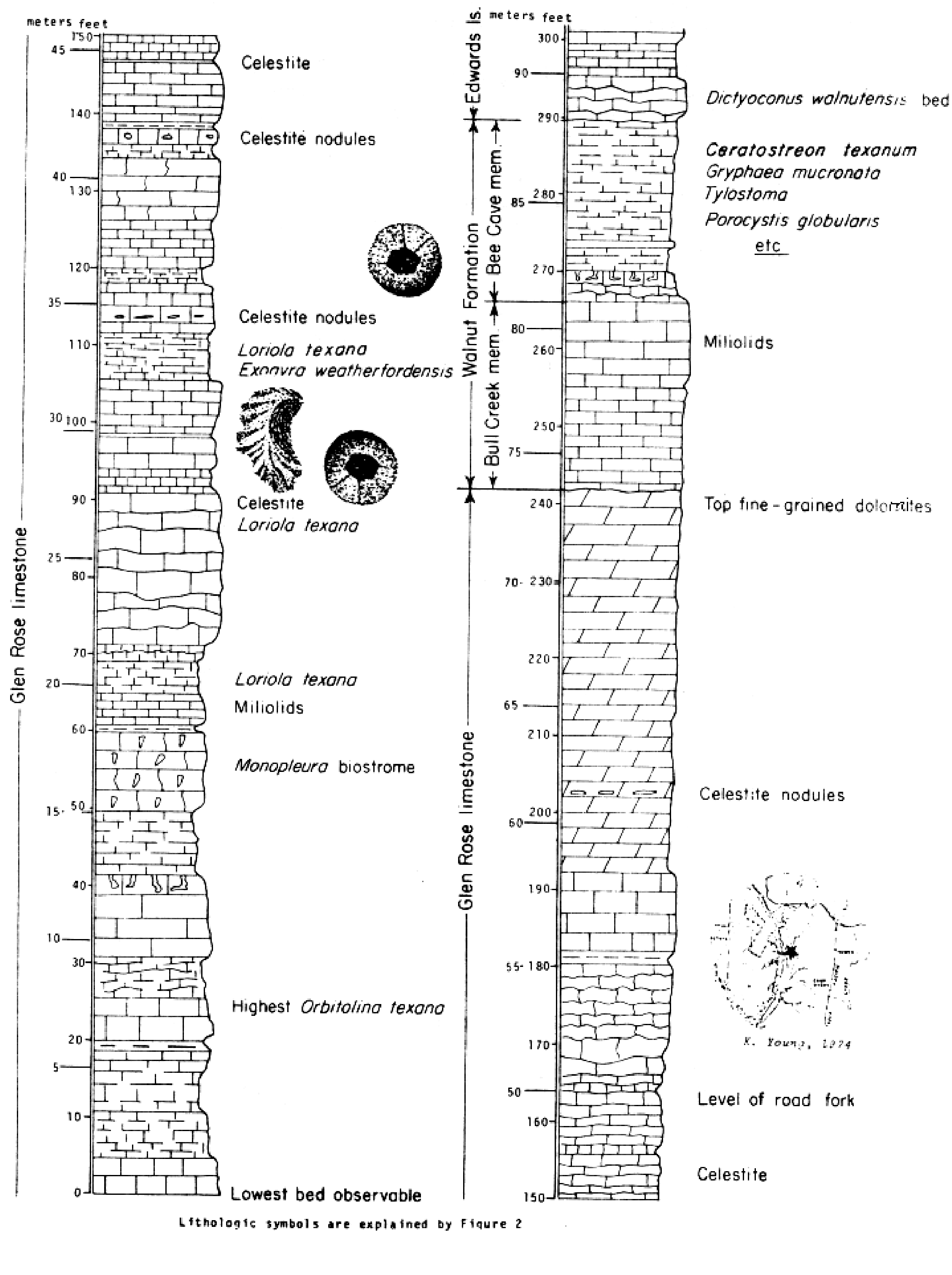


FIG. 6
SYMBOLS FOR STRATIGRAPHIC SECTIONS

FIGURE 7

MOUNT BONNELL



Lithologic symbols are explained by Figure 2

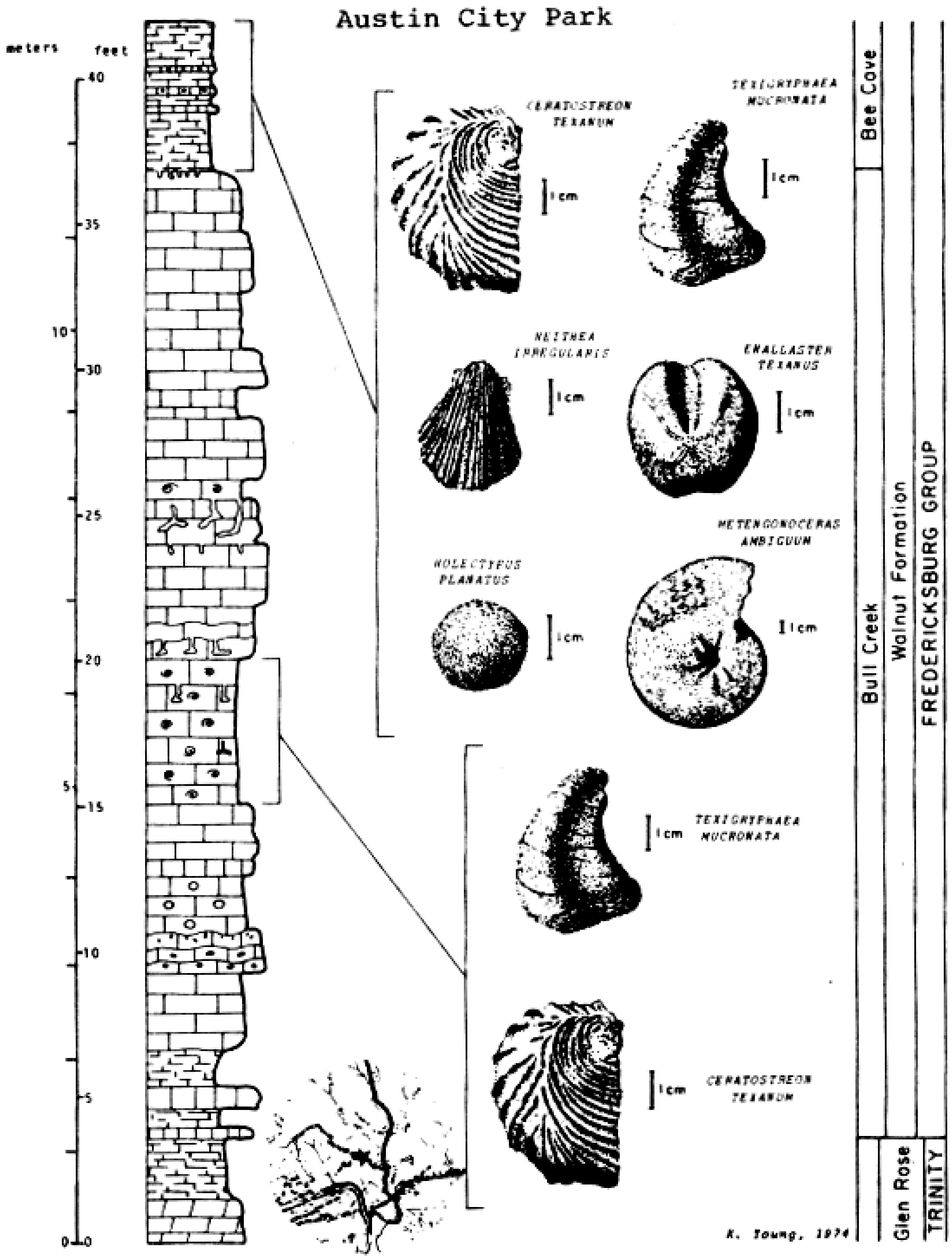
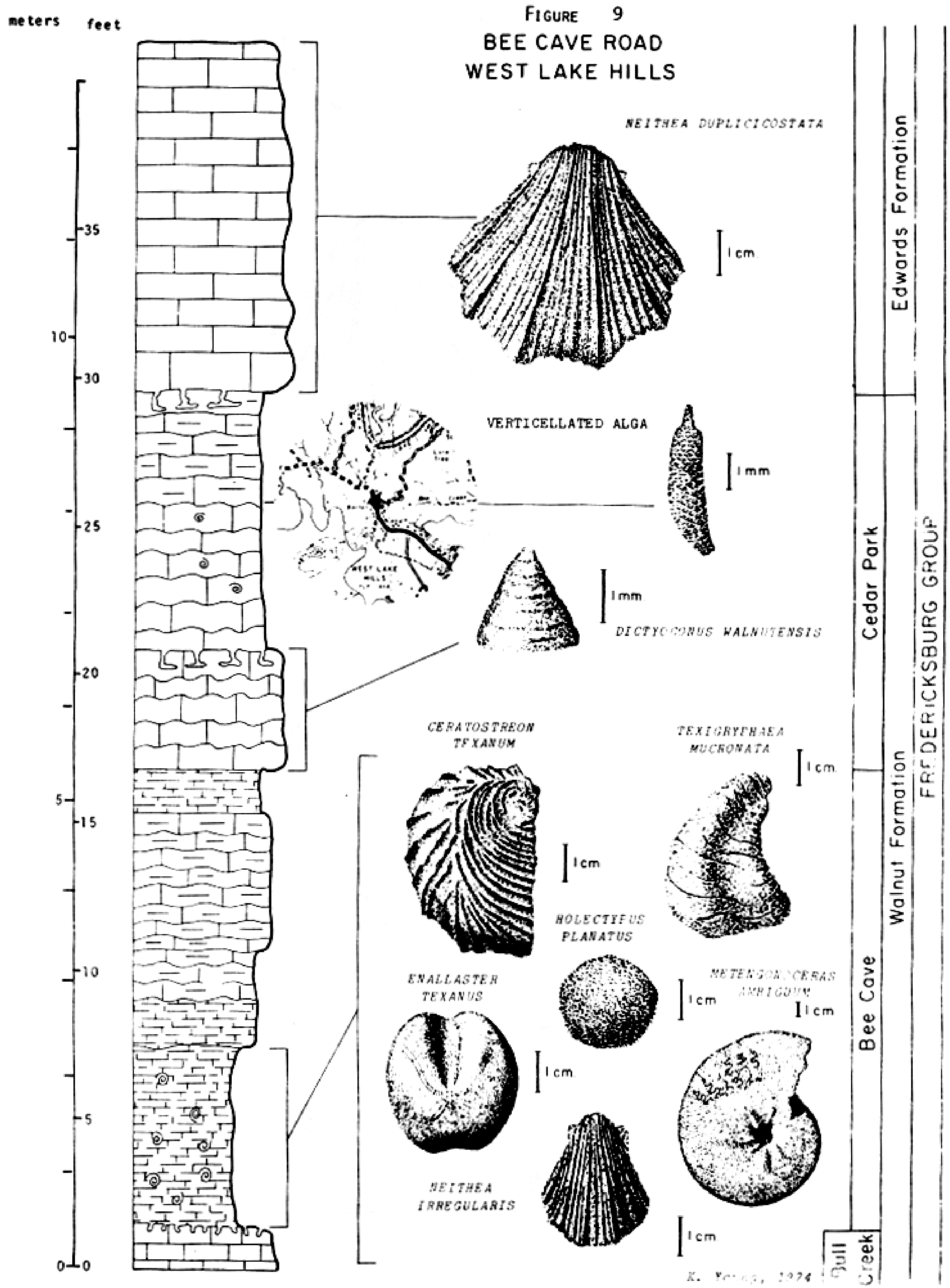
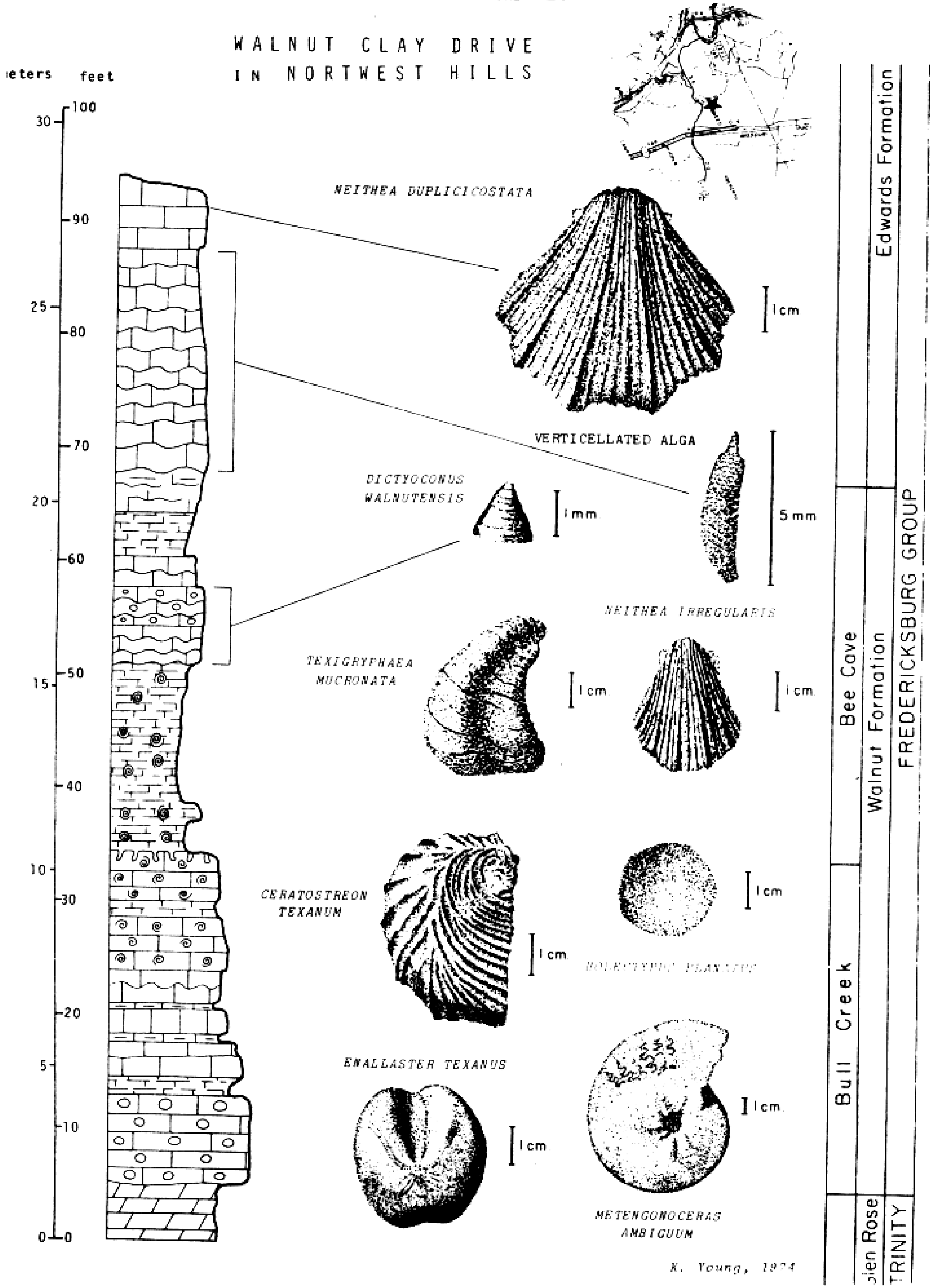

Austin City Park
meters
feet
CERATOSTREON TEXANUM
TEXIGRYPHAEA MUCRONATA
NEITHEA IRREGULARIS
ENALLASTER TEXANUS
METENGONOCERAS AMBIGUUM
HOLECTYPUS PLANATUS
TEXIGRYPHAEA MUCRONATA
CERATOSTREON TEXANUM
1cm
Bee Cove
Bull Creek
Walnut Formation
FREDERICKSBURG GROUP
Glen Rose
TRINITY
K. Young, 1974

FIGURE 8



meters
feet
FIGURE 9
BEE CAVE ROAD
WEST LAKE HILLS
NEITHEA DUPLICICOSTATA
1 cm
VERTICELLATED ALGA
1 mm
1 mm
DICTYOCONUS WALNUTENSIS
CERATOSTREON TEXANUM
TEXIGRYPHAEA MUCRONATA
1 cm
1 cm
HOLECTYPUS PLANATUS
ENALLASTER TEXANUS
1 cm
1 cm
1 cm
NEITHEA IRREGULARIS
1 cm
Edwards Formation
Cedar Park
Walnut Formation
Bee Cave
Bull Creek
FREDERICKSBURG GROUP
0
5
10
0
5
10
15
20
25
30
35

FIGURE 10


WALNUT CLAY DRIVE
IN NORTWEST HILLS
meters
feet
NEITHEA DUPLICICOSTATA
1cm
VERTICELLATED ALGA
5mm
DICTYOCONUS WALNUTENSIS
1mm
NEITHEA IRREGULARIS
TEXIGRYPHAEA MUCRONATA
1cm
CERATOSTREON TEXANUM
ENALLASTER TEXANUS
METENGONOCERAS AMBIGUUM
Edwards Formation
Bee Cave
Walnut Formation
FREDERICKSBURG GROUP
Bull Creek
TRINITY

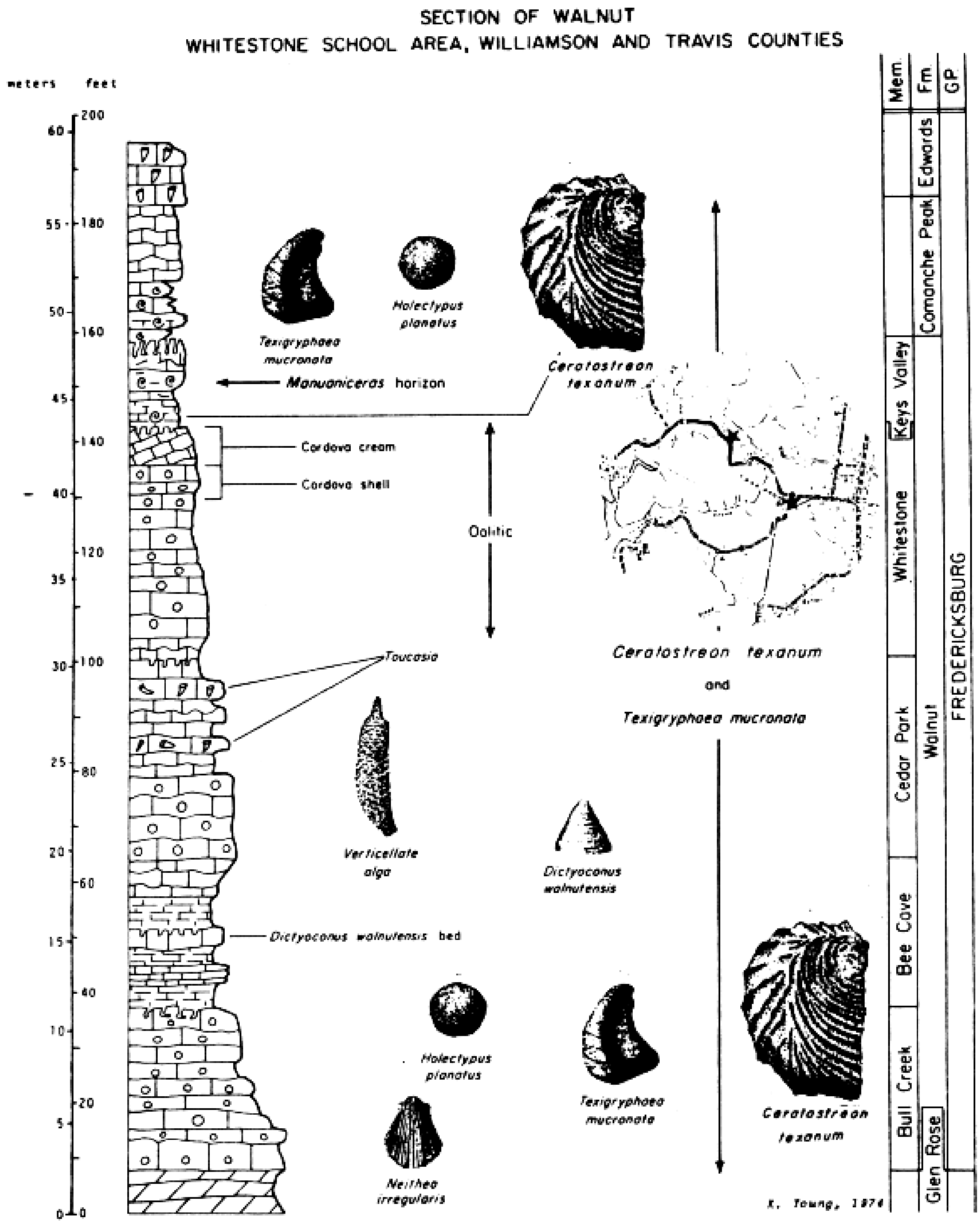
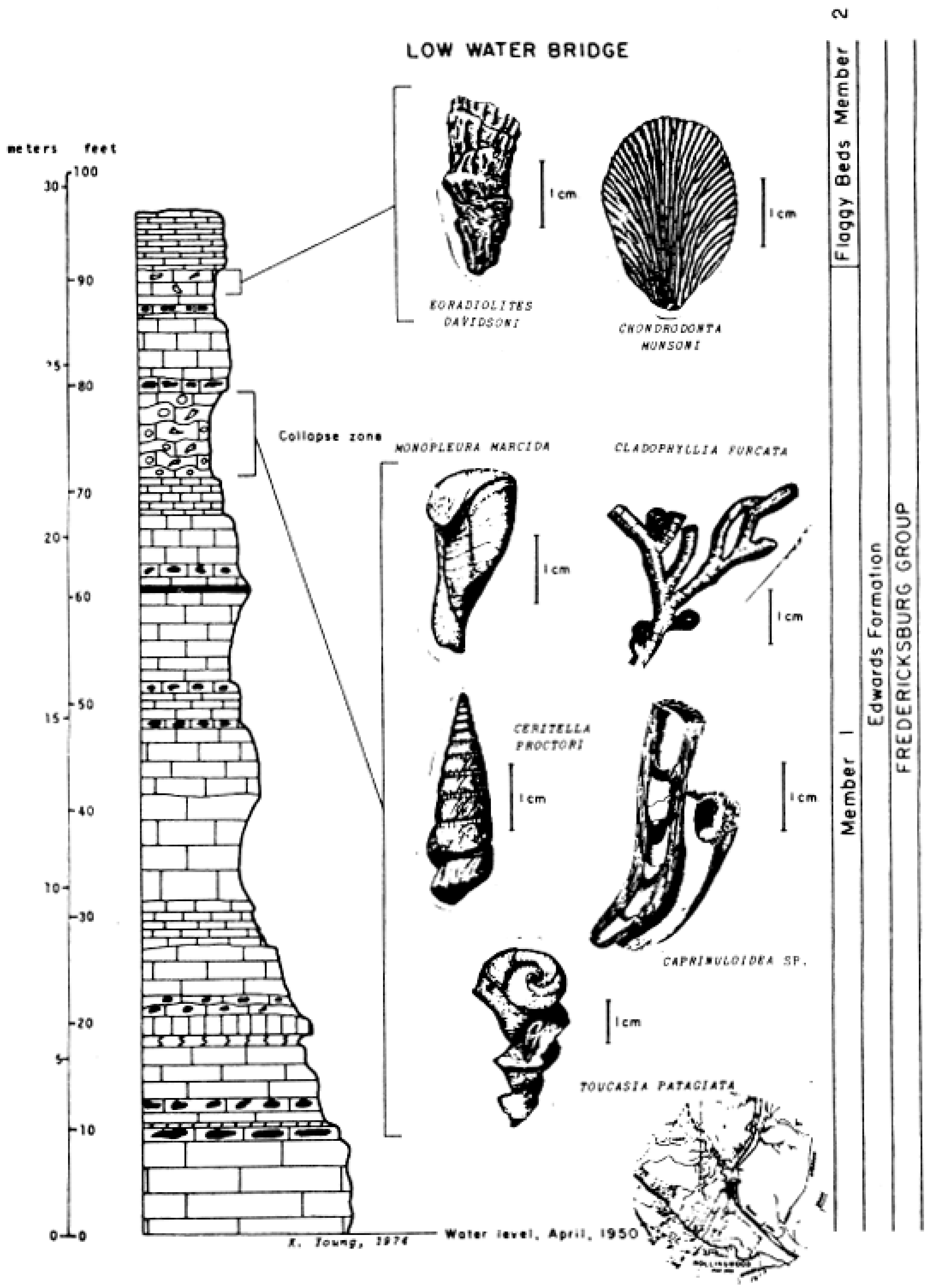
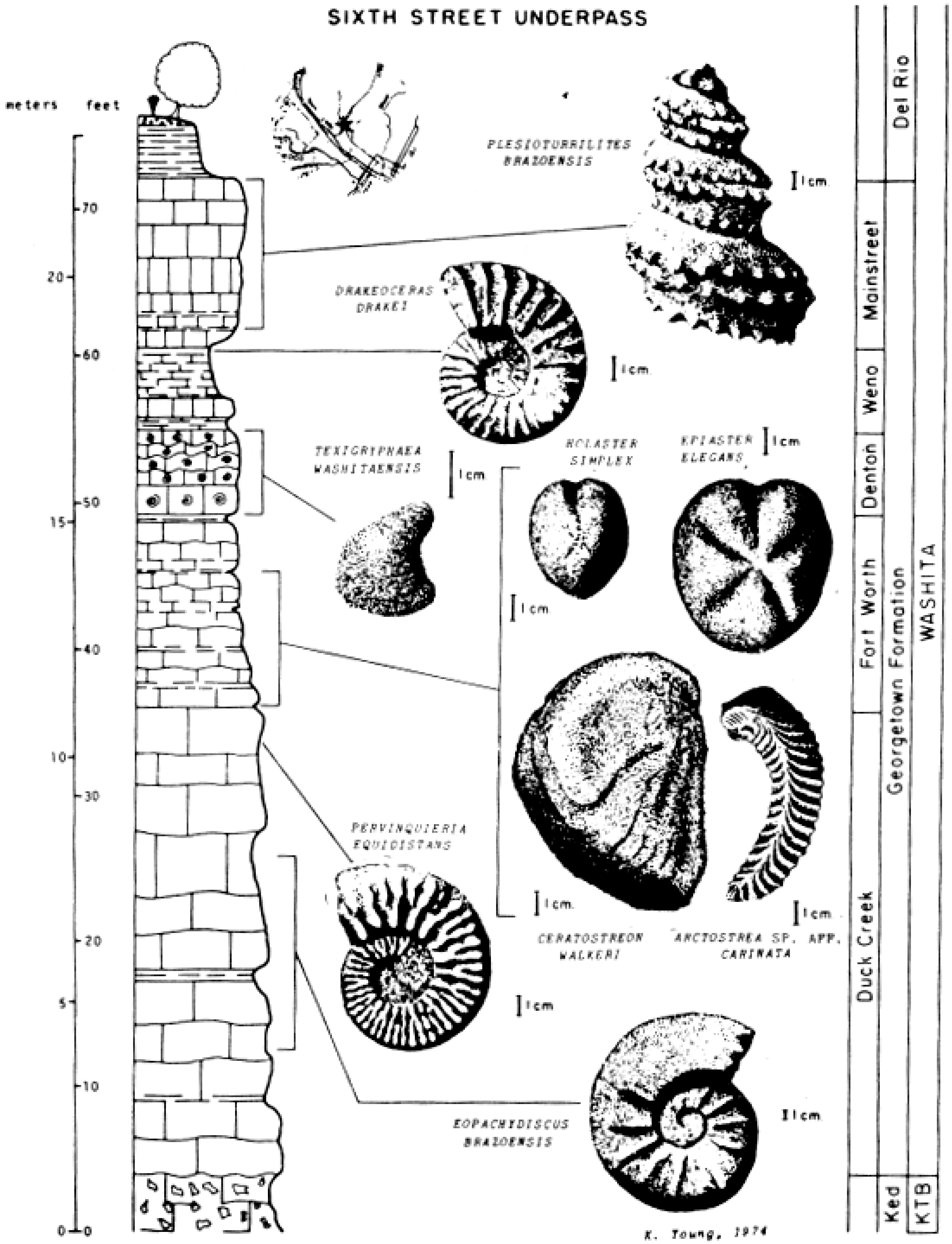

SECTION OF WALNUT
WHITESTONE SCHOOL AREA, WILLIAMSON AND TRAVIS COUNTIES
meters feet
Texigryphaea mucronata
Holectypus planatus
Ceratostreon texanum
Manuaniceras horizon
Cordova cream
Cordova shell
Oolitic
Toucasia
Ceratostreon texanum
and
Texigryphaea mucronata
Verticellate alga
Dictyoconus walnutensis
Dictyoconus walnutensis bed
Holectypus planatus
Texigryphaea mucronata
Ceratostreon texanum
Neithea irregularis
K. Young, 1974
Mem.
Fm.
GP.
Edwards
Comanche Peak
Keys Valley
Whitestone
Cedar Park
Bee Cave
Bull Creek
Walnut
Glen Rose
FREDERICKSBURG

FIGURE 11



LOW WATER BRIDGE
meters
feet
30
25
20
15
10
5
0
100
90
80
70
60
50
40
30
20
10
0
Collapse zone
EORADIOLITES DAVIDSONI
CHONDRODONTA MUNSONI
MONOPLEURA MARCIDA
CLADOPHYLLIA FURCATA
CERITELLA PROCTORI
CAPRINULOIDEA SP.
TOUCASIA PATAGIATA
1 cm
K. Young, 1974
Water level, April, 1950
Flaggy Beds Member 2
Member 1
Edwards Formation
FREDERICKSBURG GROUP

FIGURE 12

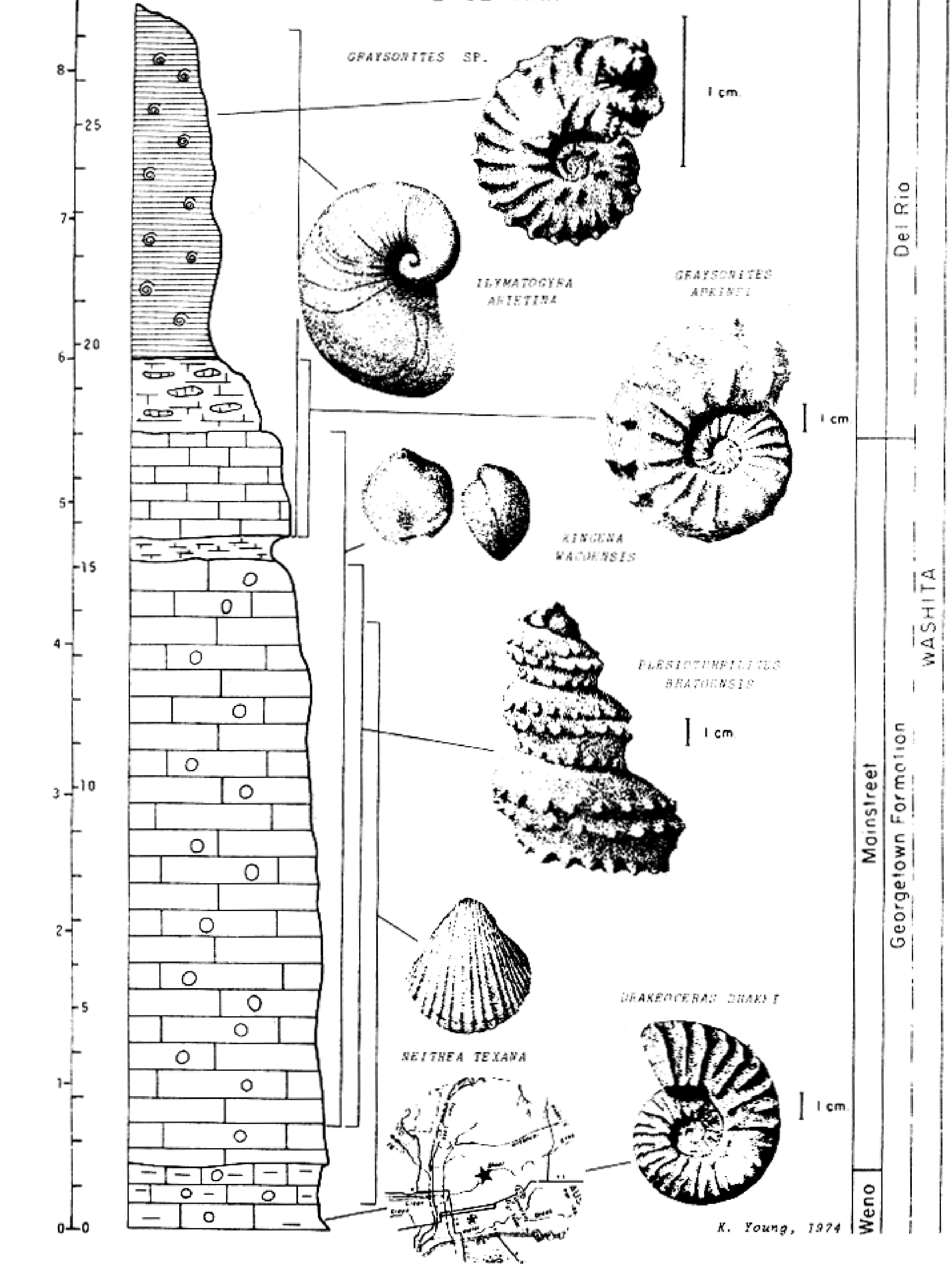


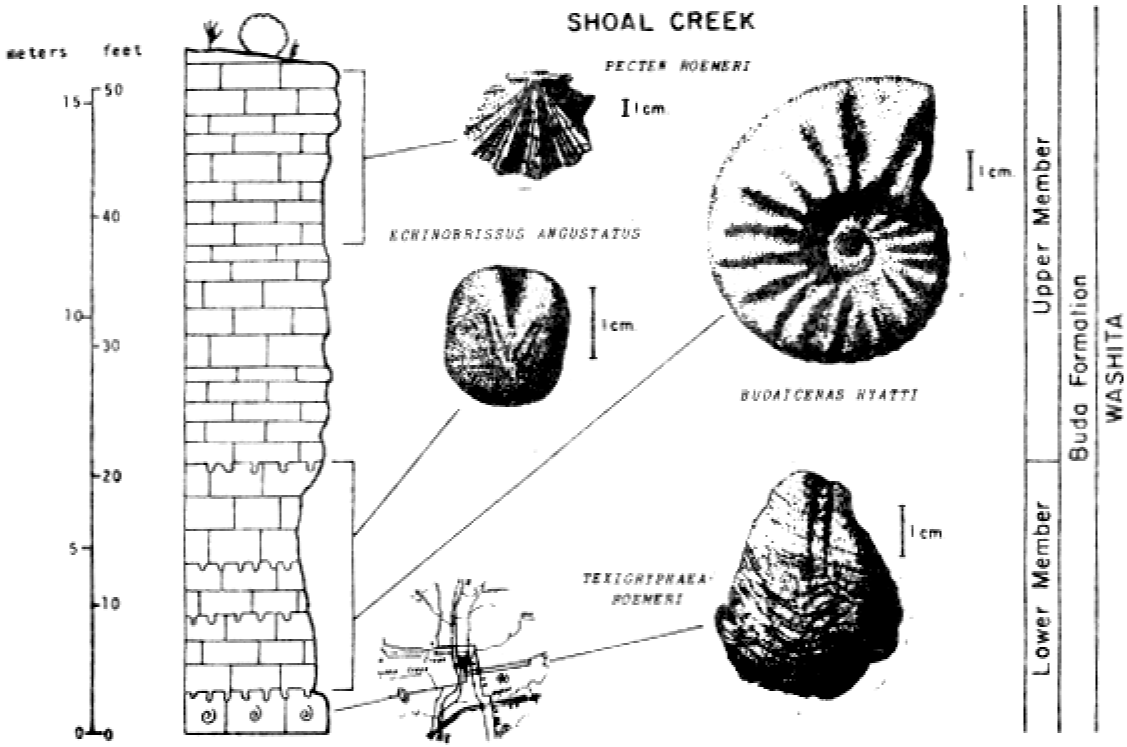
SIXTH STREET UNDERPASS
meters
feet
PLESIOTURRILITES BRAZOENSIS
DRAKEOCERAS DRAKEI
TEXIGRYPHAEA WASHITAENSIS
HOLASTER SIMPLEX
EPIASTER ELEGANS
PERVINQUIERIA EQUIDISTANS
CERATOSTREON WALKERI
ARCTOSTREA SP. AFF. CARINATA
EOPACHYDISCUS BRAZOENSIS
1 cm
K. Young, 1974
Del Rio
Mainstreet
Weno
Denton
Fort Worth
Duck Creek
Georgetown Formation
WASHITA
Ked
KTB

FIGURE 13

Figure 14

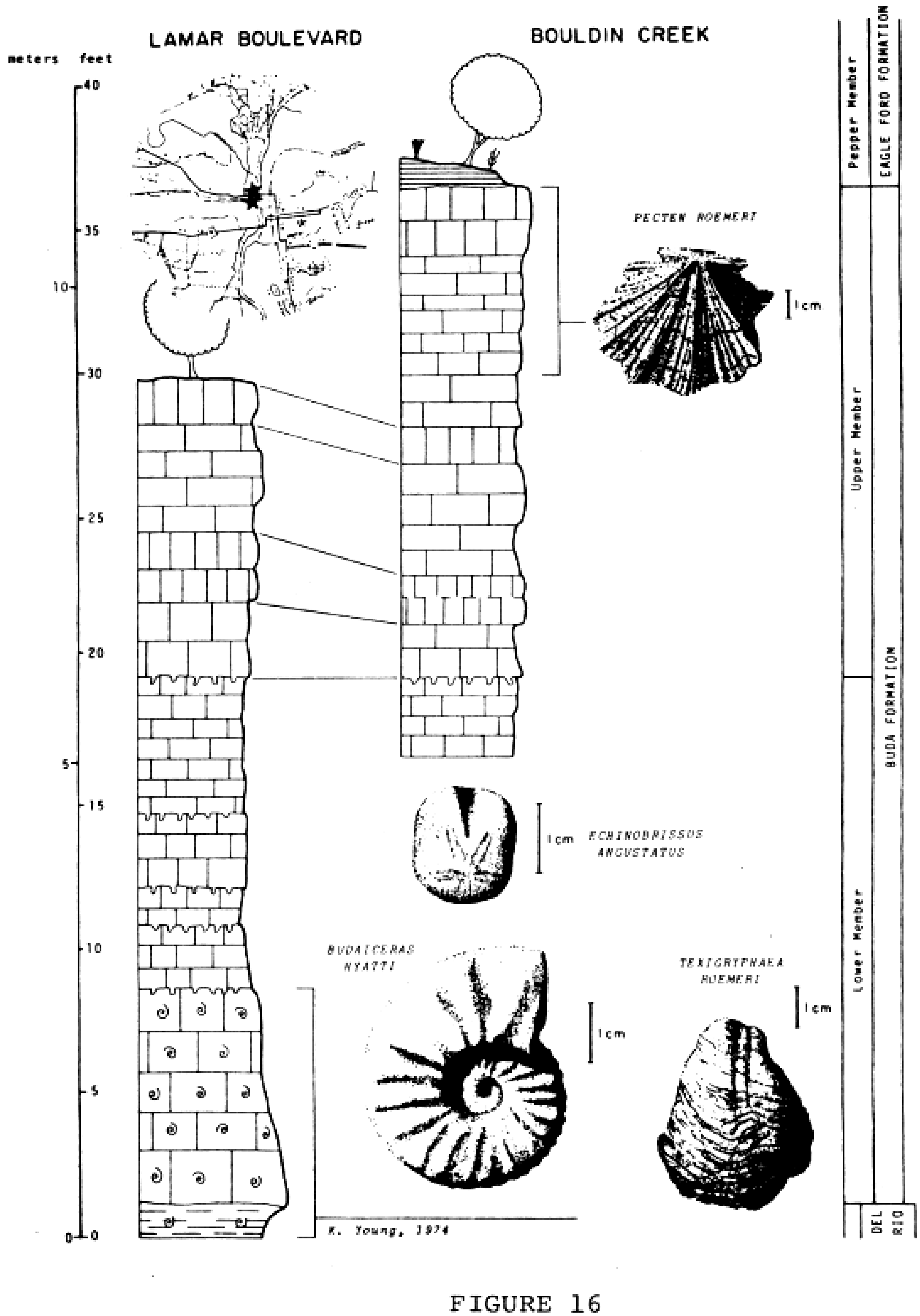
PEASE PARK





SHOAL CREEK
meters
feet
15
10
5
0
50
40
30
20
10
0
PECTEN ROEMERI
1 cm.
ECHINOBRISSUS ANGUSTATUS
1 cm.
BUDAICERAS HYATTI
1 cm.
TEXIGRYPHAEA ROEMERI
1 cm
Upper Member
Lower Member
Buda Formation
WASHITA

FIGURE 15



LAMAR BOULEVARD
BOULDIN CREEK
meters
feet
40
35
30
25
20
15
10
5
0
10
5
0
PECTEN ROEMERI
1 cm
ECHINOBRISSUS ANGUSTATUS
BUDAICERAS HYATTI
TEXIGRYPHAEA ROEMERI
K. Young, 1974
Pepper Member
EAGLE FORD FORMATION
Upper Member
Lower Member
BUDA FORMATION
DEL RIO

FIGURE 16

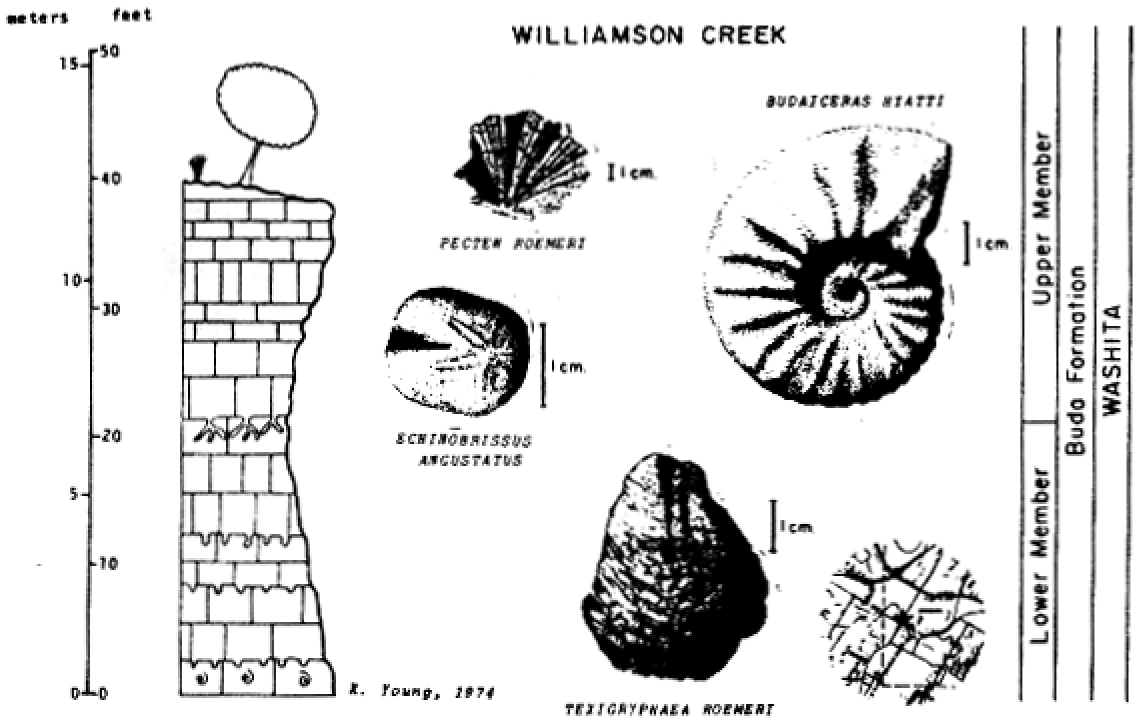
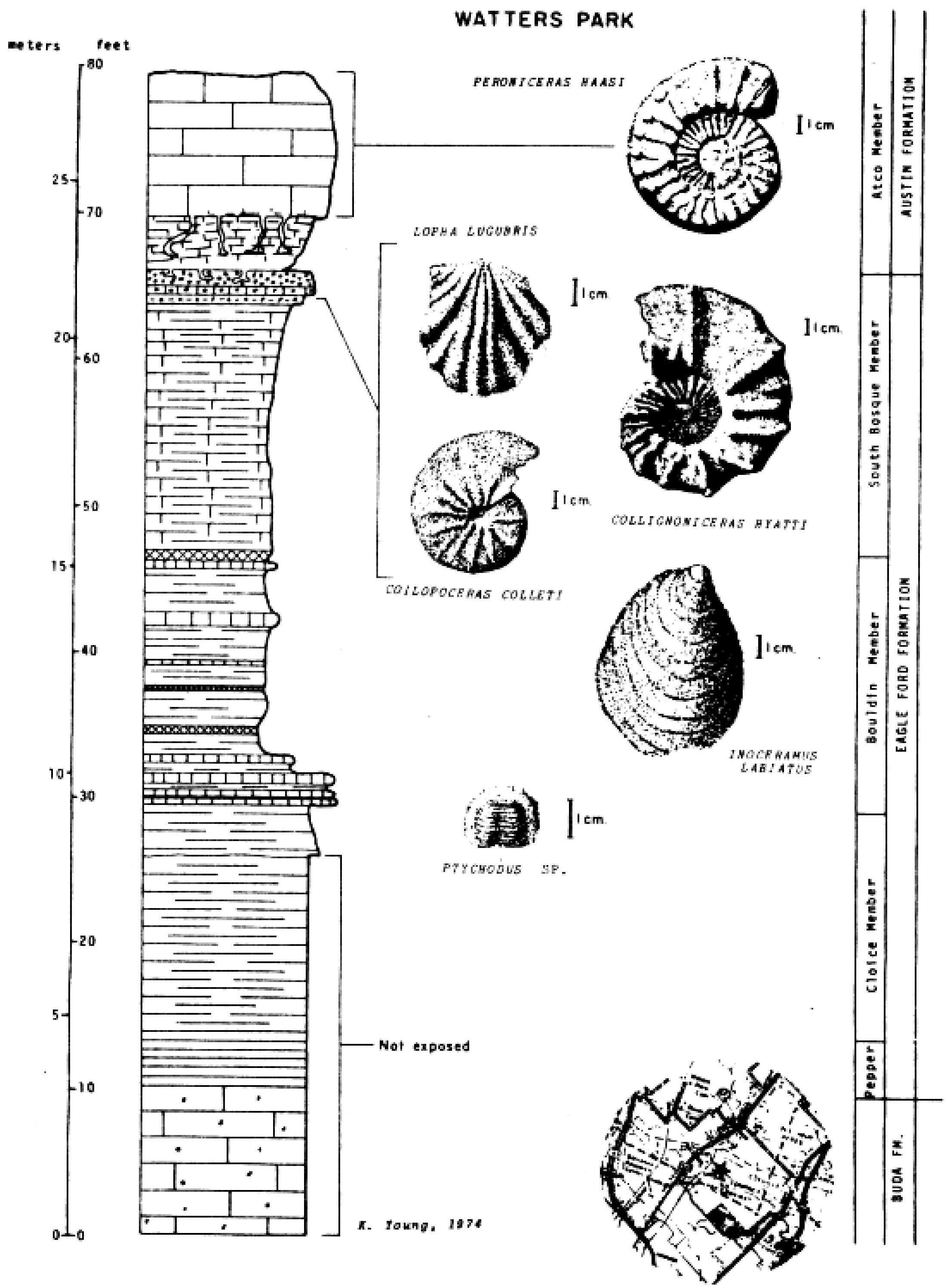

meters
feet
WILLIAMSON CREEK
BUDAICERAS HIATTI
PECTEN ROEMERI
ECHINOBRISSUS ANGUSTATUS
TEXIGRYPHAEA ROEMERI
K. Young, 1974
1 cm.
Upper Member
Lower Member
Budo Formation
WASHITA

FIGURE 17



WATTERS PARK
meters
feet
80
25
70
20
60
50
15
40
10
30
20
5
10
0
0
PERONICERAS HAASI
I cm
LOPHA LUGUBRIS
I cm
I cm.
I cm.
COLLIGNONICERAS HYATTI
COILOPOCERAS COLLETI
I cm.
INOCERAMUS LABIATUS
I cm.
PTYCHODUS SP.
Not exposed
K. Young, 1974
Atco Member
AUSTIN FORMATION
South Bosque Member
Bouldin Member
EAGLE FORD FORMATION
Cloice Member
Pepper
BUDA FM.

FIGURE 18

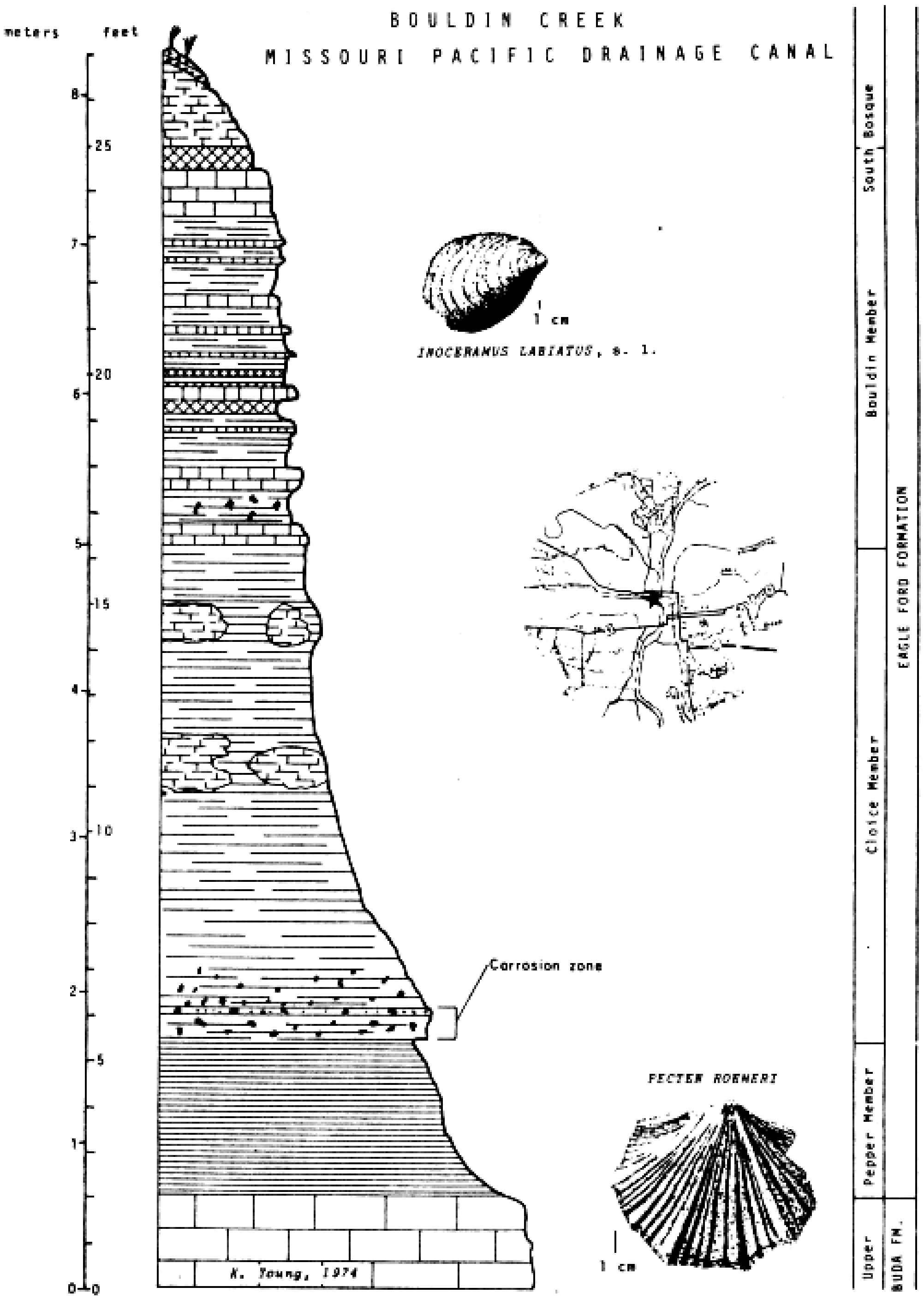

BOULDIN CREEK
MISSOURI PACIFIC DRAINAGE CANAL
meters
feet
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
INOCERAMUS LABIATUS, s. l.
1 cm
Corrosion zone
PECTEN ROEMERI
1 cm
K. Young, 1974
South Bosque
Bouldin Member
Cloice Member
Pepper Member
Upper
EAGLE FORD FORMATION
BUDA FM.

FIGURE 19

BOULDIN CREEK AT AT MILTON STREET

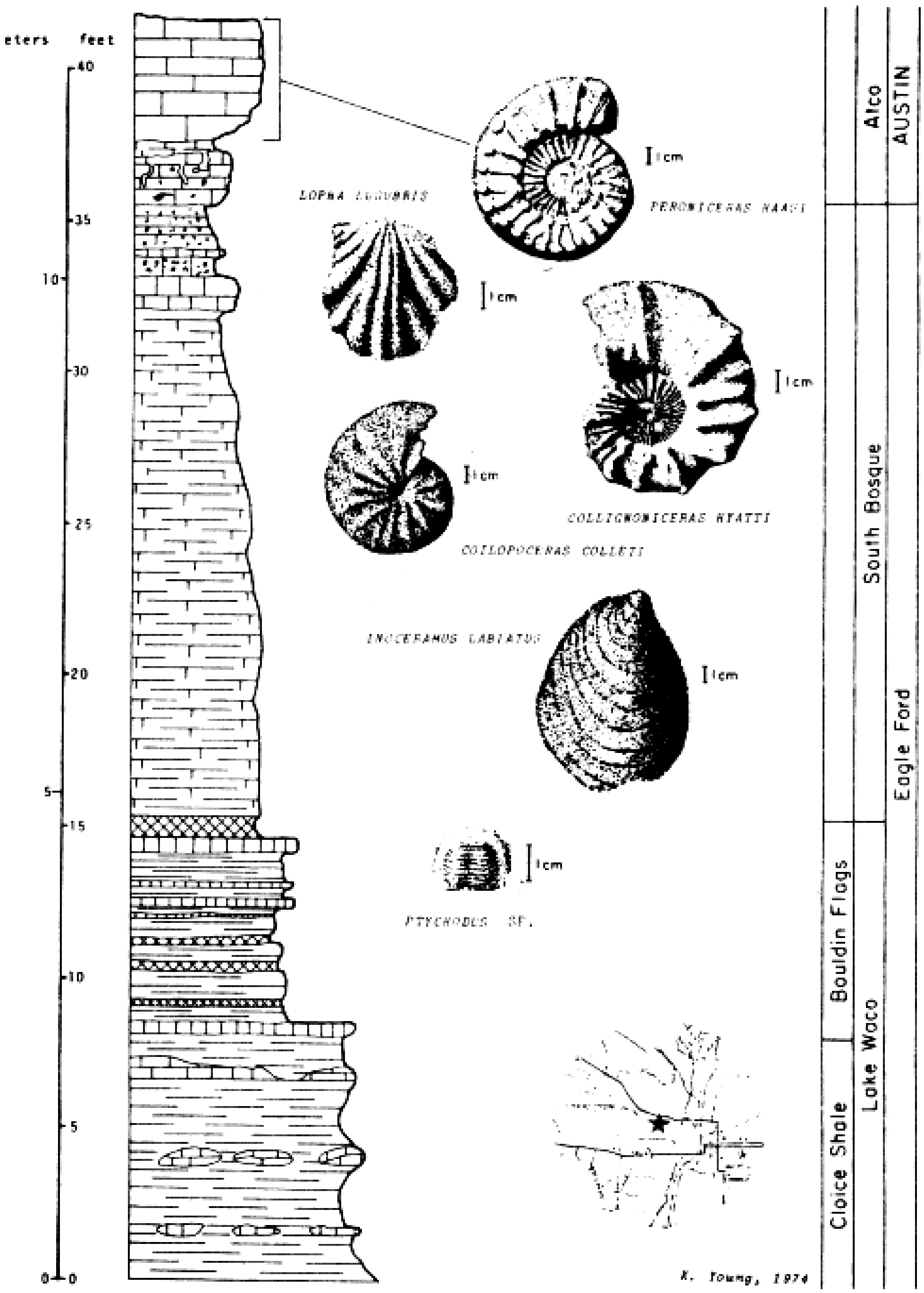
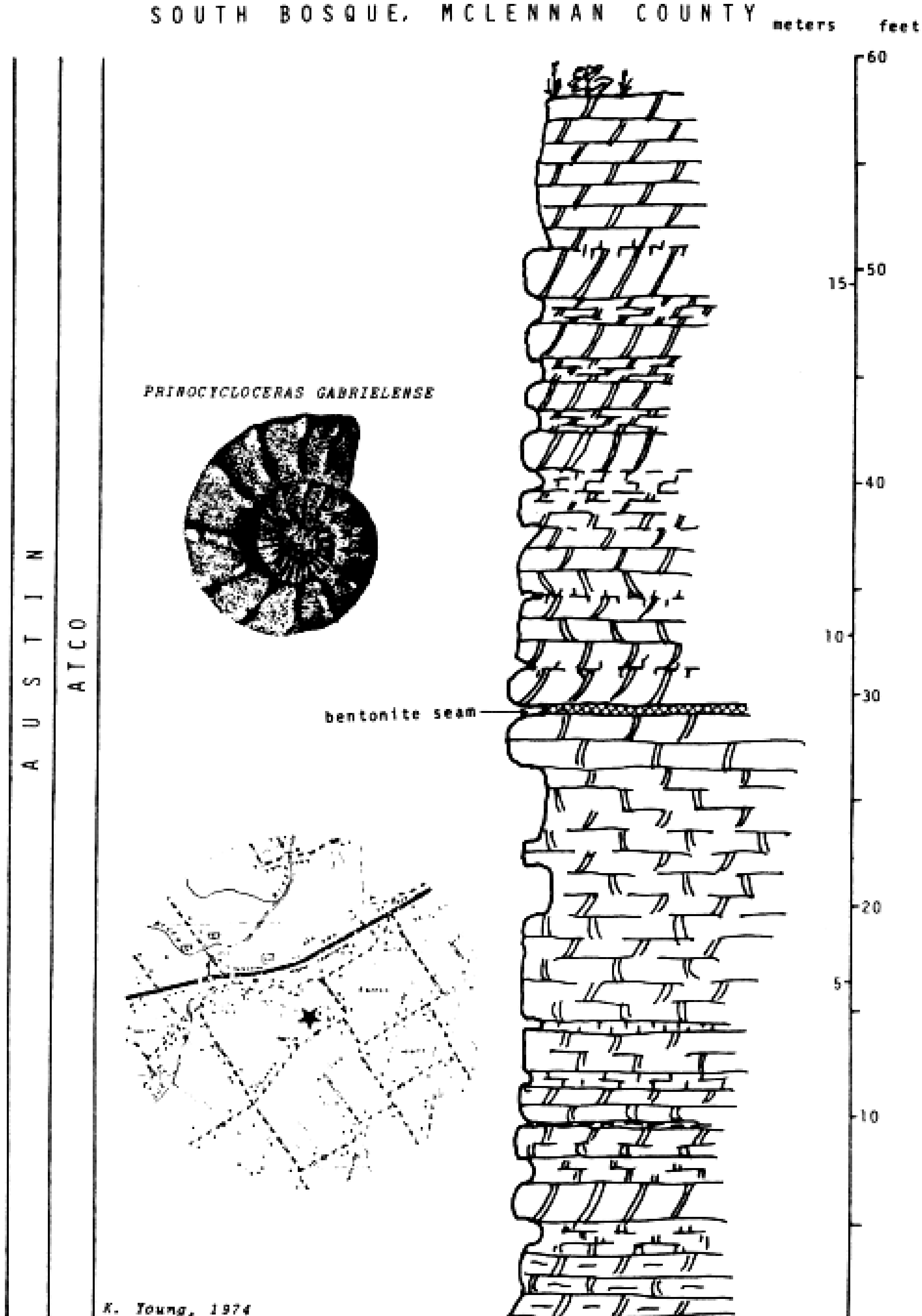


FIGURE 20

FIGURE 21

ATLAS CEMENT COMPANY QUARRY

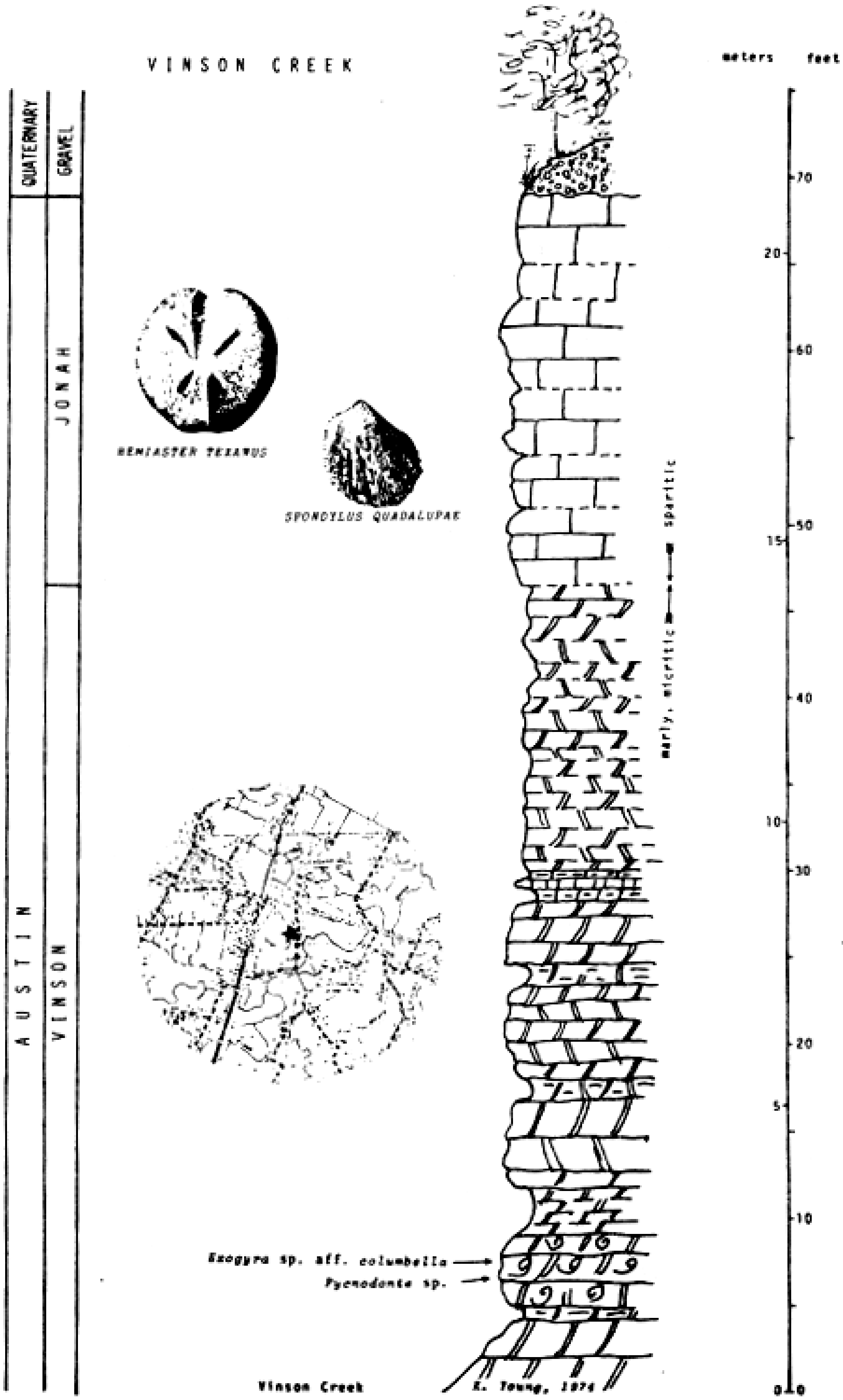
SOUTH BOSQUE, MCLENNAN COUNTY



K. Young, 1974

Section measured by K. O. Seewald

FIGURE 22



VINSON CREEK
meters
feet
QUATERNARY
GRAVEL
AUSTIN
JONAH
VINSON
HEMIASTER TEXANUS
SPONDYLUS QUADALUPAE
marly, micritic
sparitic
Exogyra sp. aff. columbella
Pycnodonte sp.
Vinson Creek
K. Young, 1974
0
5
10
15
20
10
20
30
40
50
60
70

FIGURE 23

SAN GABRIEL RIVER AT JONAH

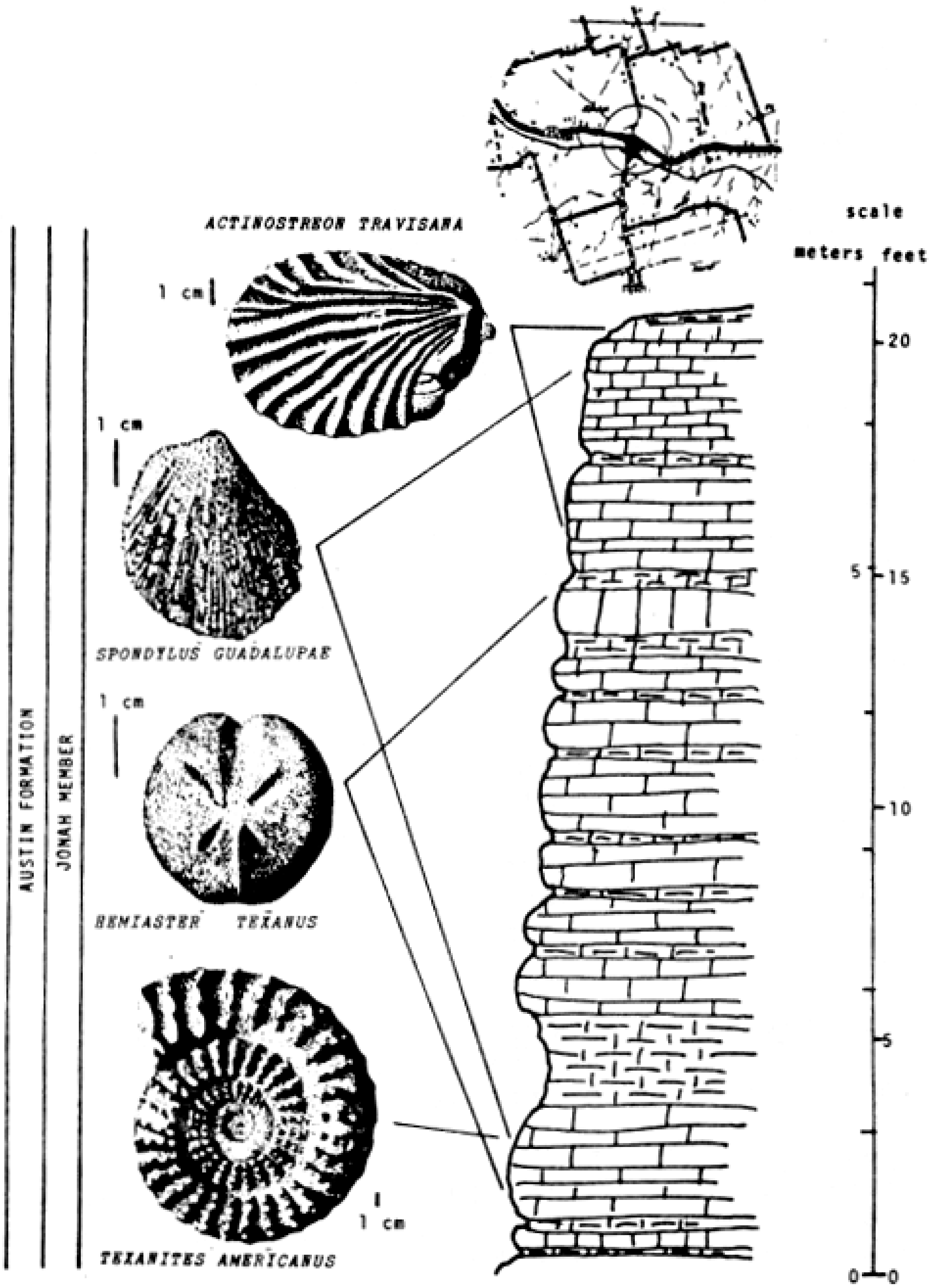


FIGURE 24

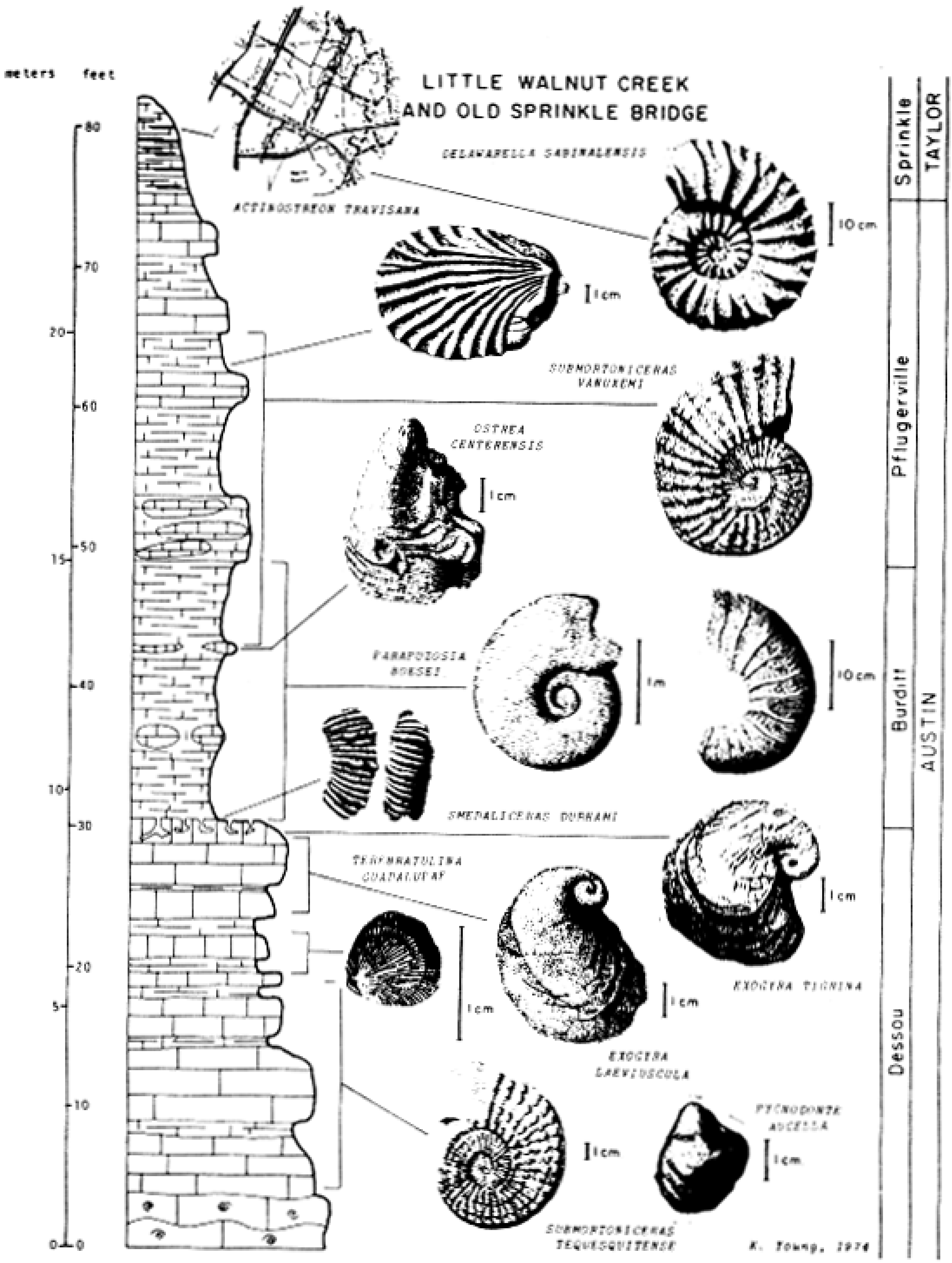
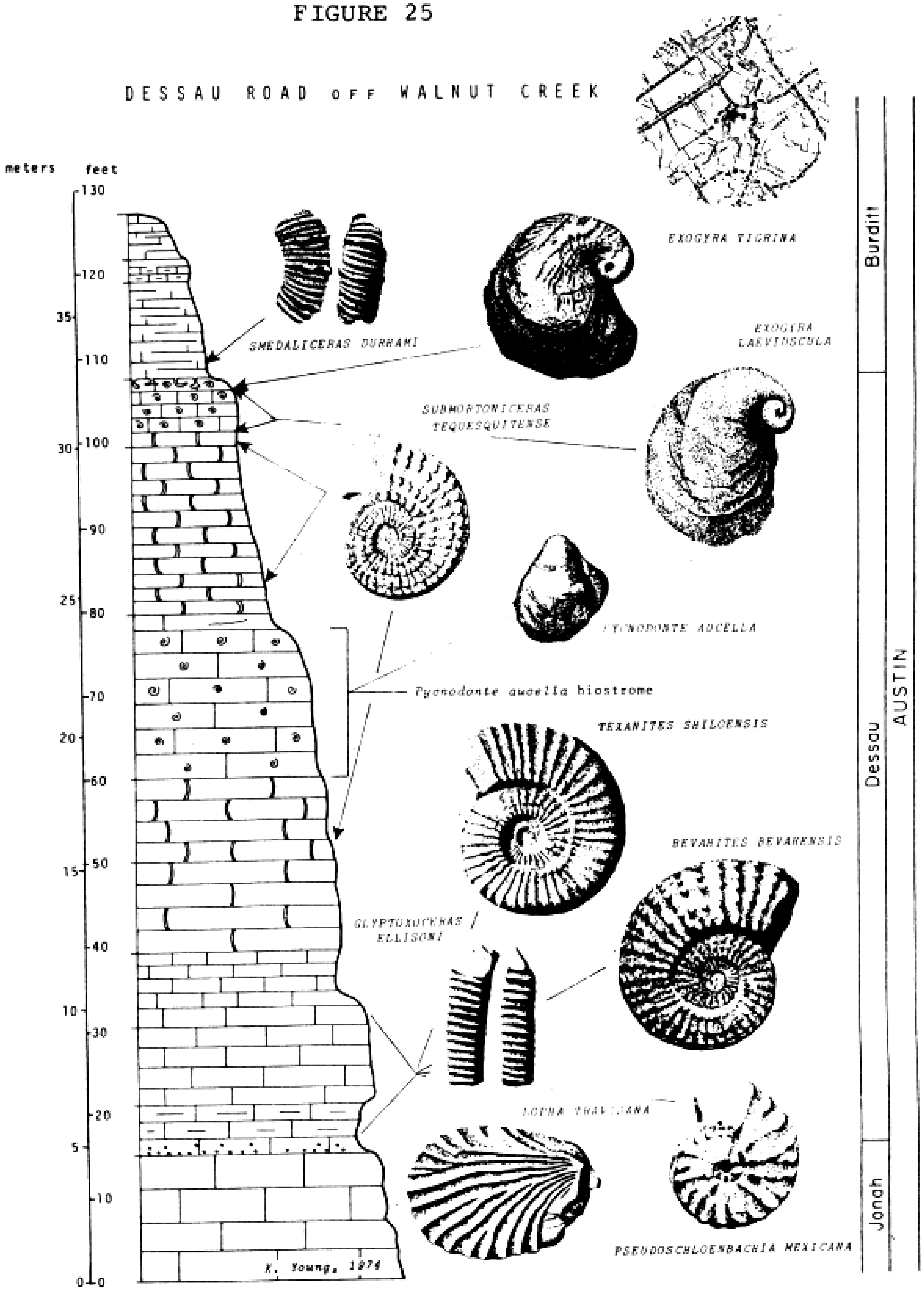

LITTLE WALNUT CREEK
AND OLD SPRINKLE BRIDGE
meters
feet
DELAWARELLA SABINALENSIS
ACTINOSTREON TRAVISANA
SUBMORTONICERAS
VANUXEMI
OSTREA
CENTERENSIS
PARAPUZOSIA
BOESEI
TEREBRATULINA
GUADALUPAE
EXOGYRA TIGRINA
EXOGYRA
LAEVIUSCULA
PYCNODONTE
AUCELLA
SUBMORTONICERAS
TEQUESQUITENSE
K. Young, 1974
10 cm
1 cm
1 m
Sprinkle
Pflugerville
Burditt
Dessau
TAYLOR
AUSTIN

FIGURE 25



DESSAU ROAD OFF WALNUT CREEK
meters
feet
SMEDALICERAS DURHAMI
EXOGYRA TIGRINA
EXOGYRA LAEVIUSCULA
SUBMORTONICERAS TEQUESQUITENSE
Pycnodonte aucella biostrome
TEXANITES SHILOENSIS
BEVAHITES BEVAHENSIS
GLYPTOXOCERAS ELLISONI
PSEUDOSCHLOENBACHIA MEXICANA
K. Young, 1974
Burditt
Dessau
Jonah
AUSTIN

FIGURE 26

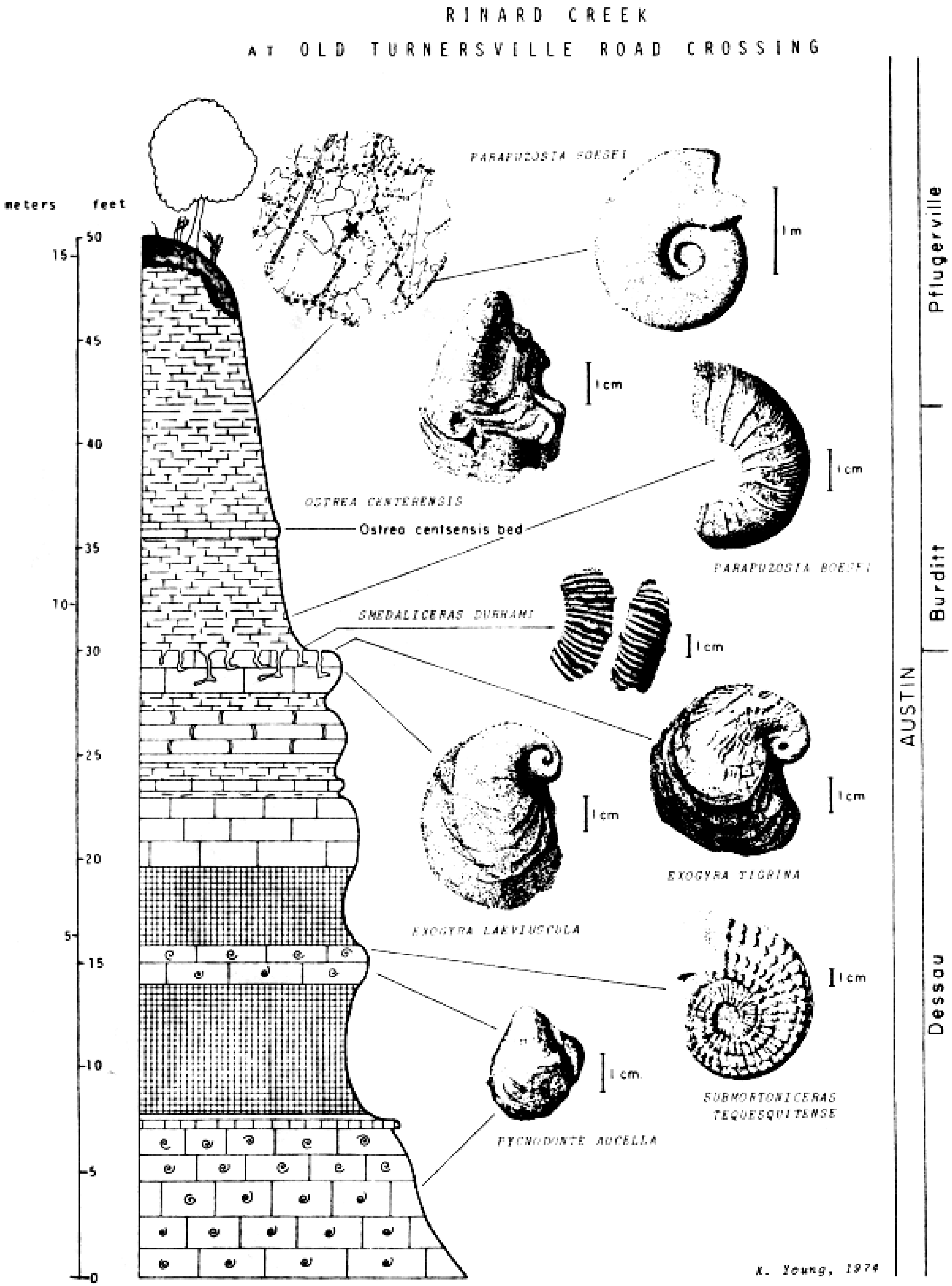
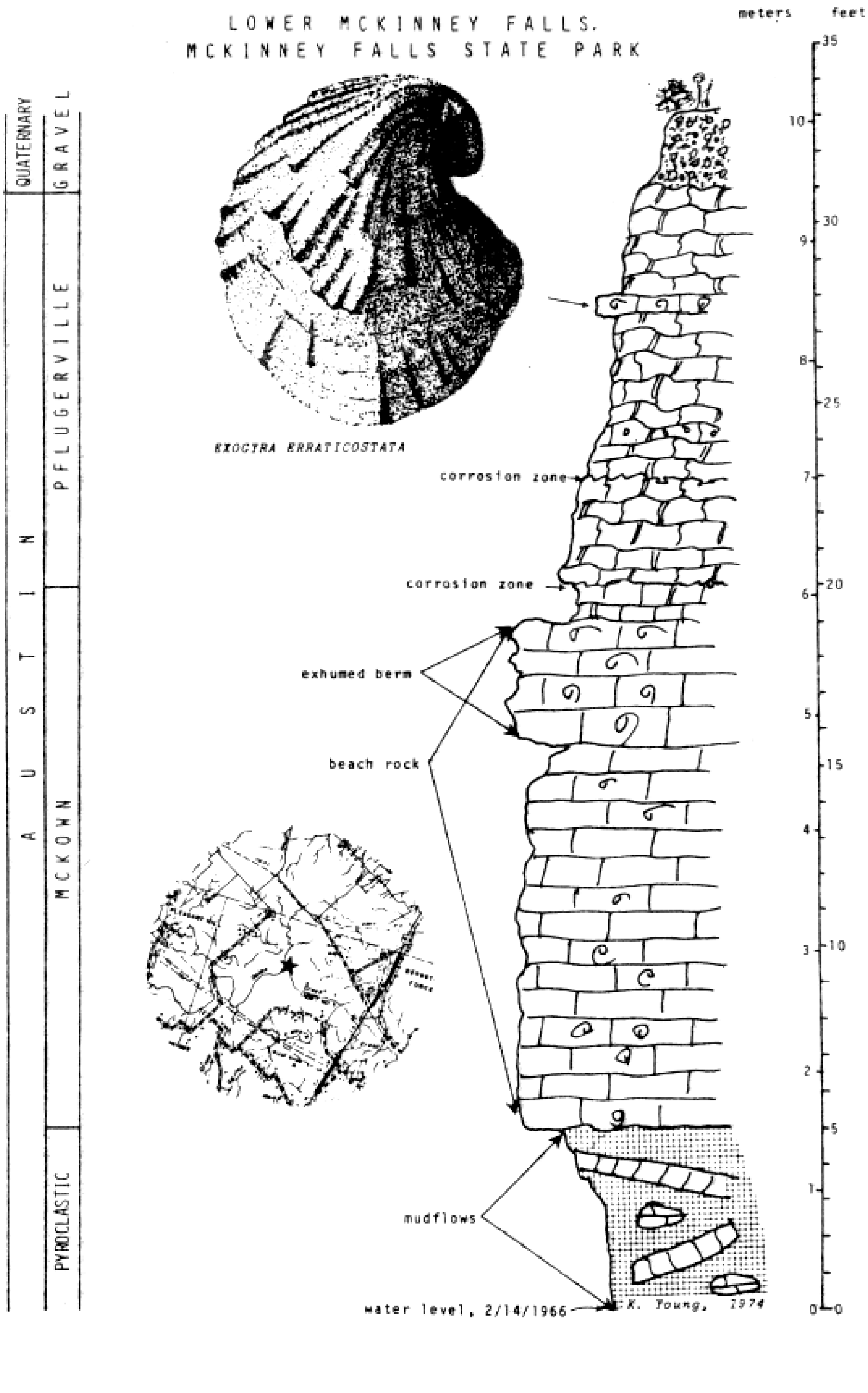

RINARD CREEK
AT OLD TURNERSVILLE ROAD CROSSING
meters
feet
PARAPUZOSIA BOESEI
1 m
1 cm
OSTREA CENTERENSIS
Ostrea centsensis bed
1 cm
PARAPUZOSIA BOESEI
SMEDALICERAS DURHAMI
1 cm
1 cm
1 cm
EXOGYRA TIGRINA
EXOGYRA LAEVIUSCULA
1 cm
1 cm.
SUBMORTONICERAS TEQUESQUITENSE
PYCNODONTE AUCELLA
K. Young, 1974
Pflugerville
Burditt
Dessau
AUSTIN

FIGURE 27

LOWER MCKINNEY FALLS,
MCKINNEY FALLS STATE PARK



RIM ROCK SECTION
(2500 feet west of Pilot Knob School)

K. Young, 1974

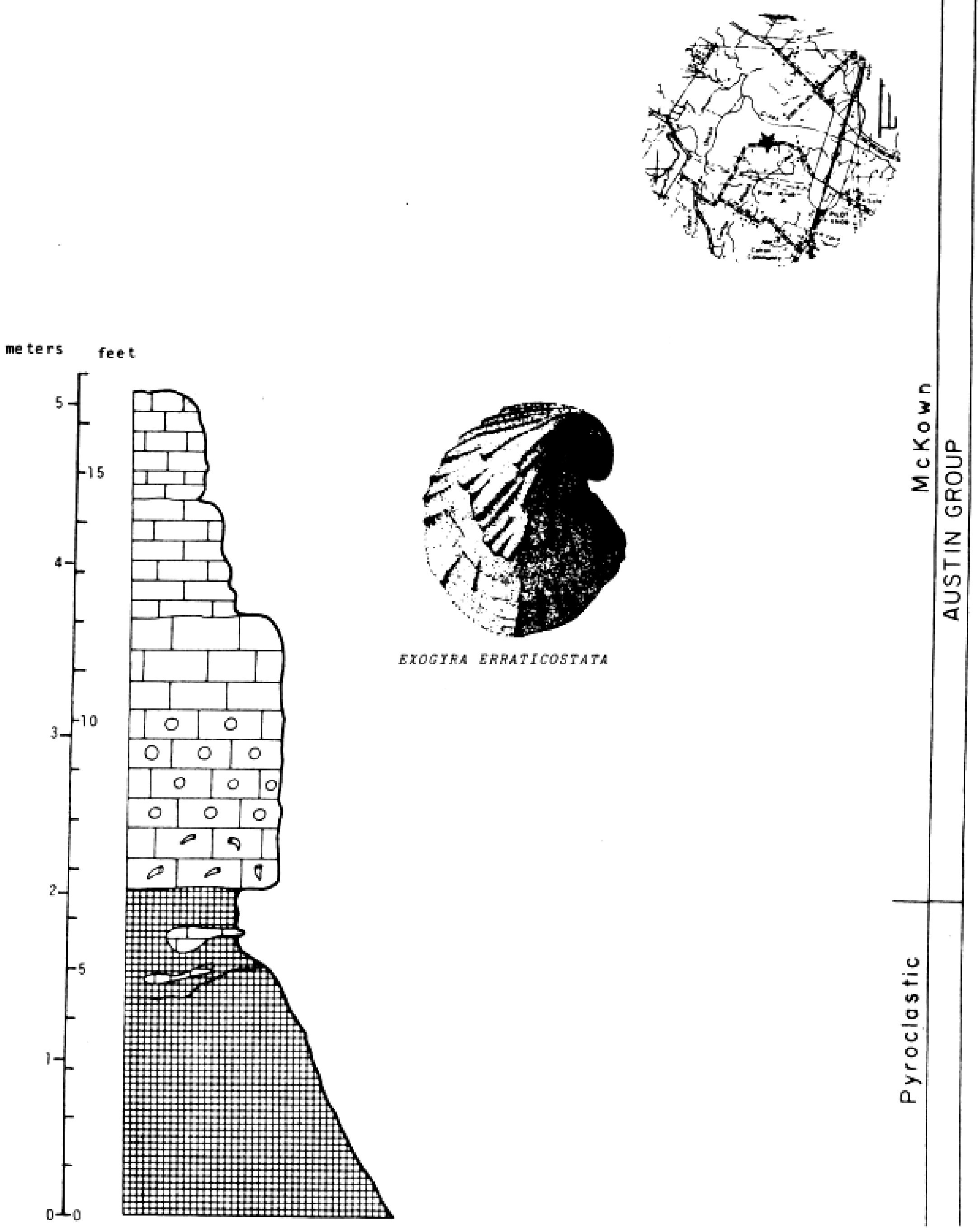


FIGURE 28

FIGURE 29

LITTLE WALNUT CREEK
JUST NORTH OF MANOR HIGHWAY

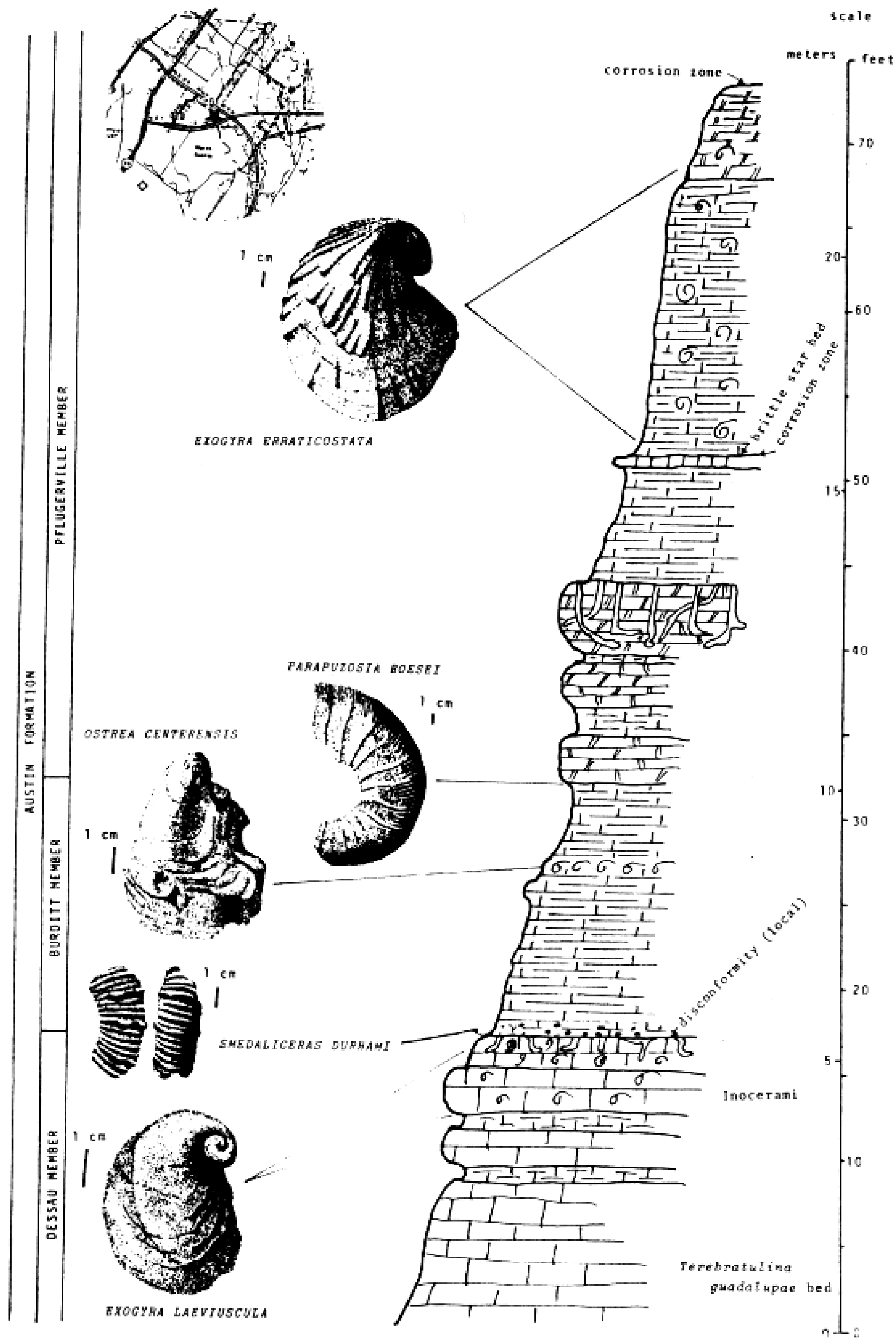
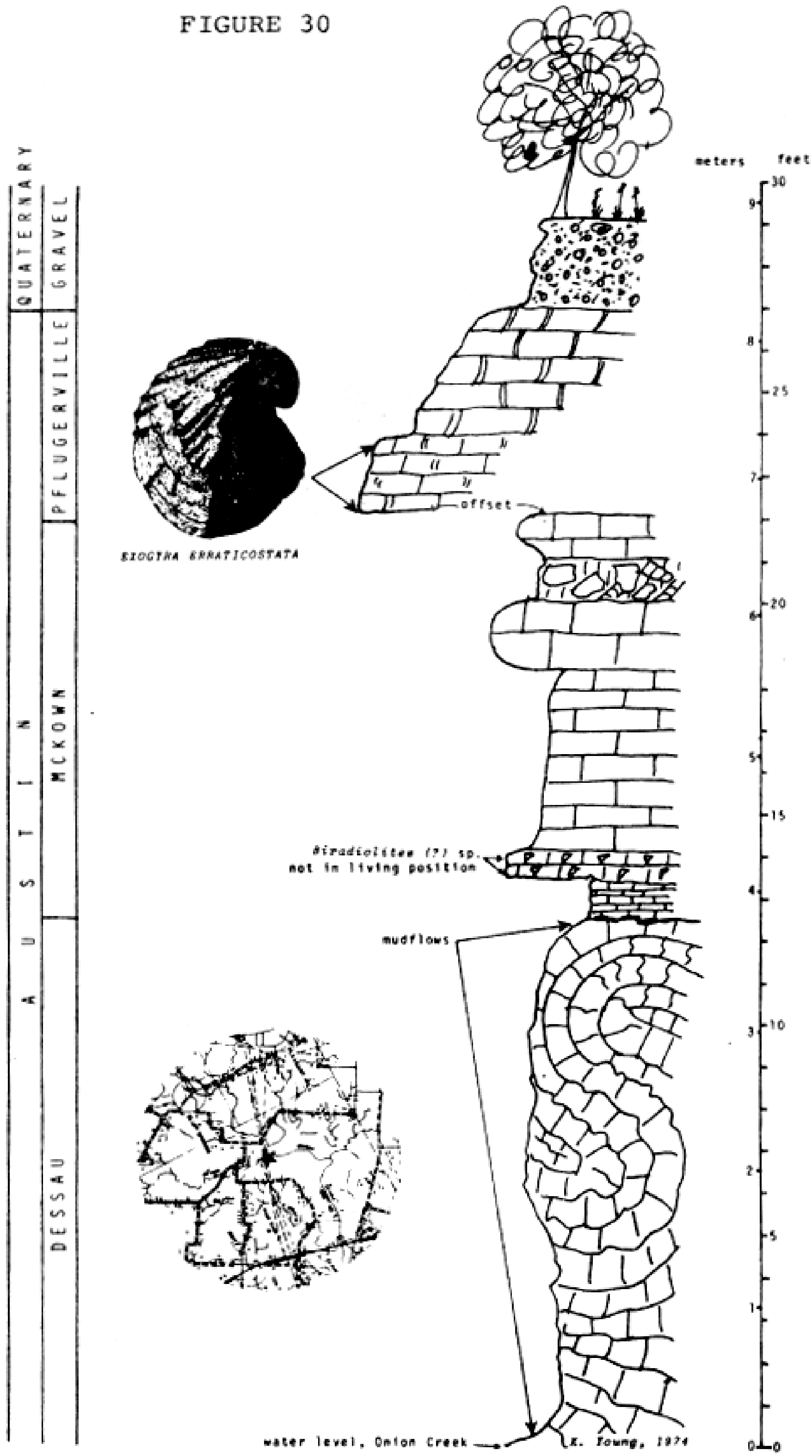


FIGURE 30



SECTION AT JANE'S FARM,
MOUTH OF MARBLE CREEK

FIGURE 31

SPRINGDALE ROAD

AT LITTLE WALNUT CREEK

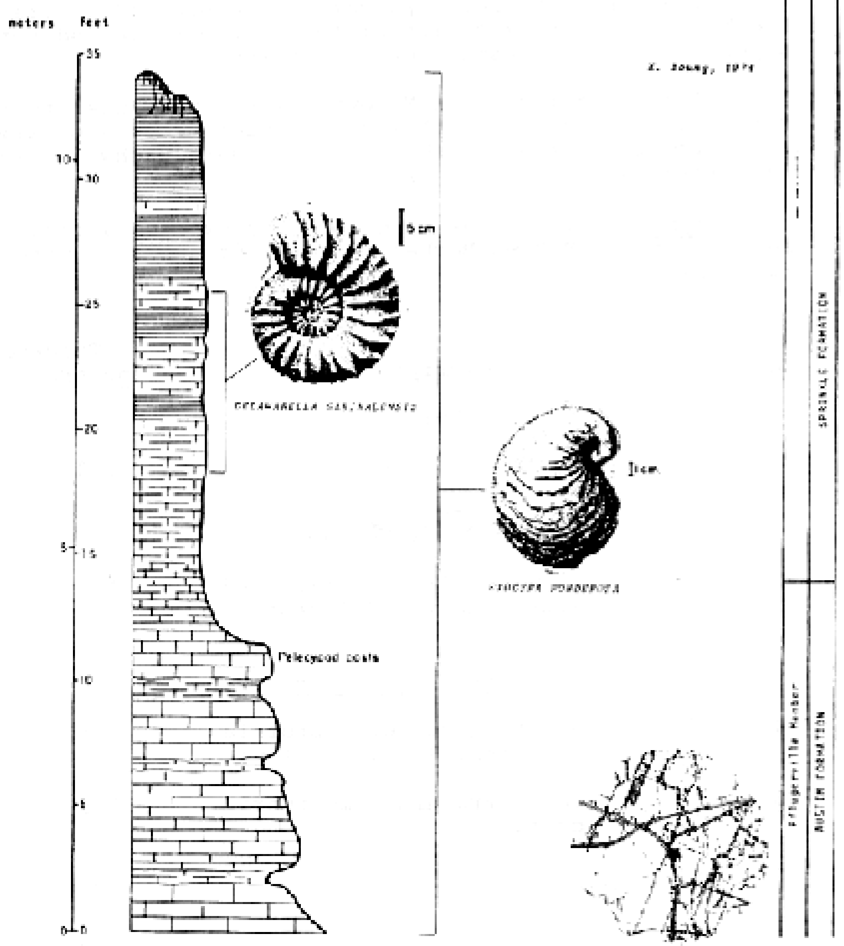


FIGURE 32
SOUTH BANK OF WALNUT CREEK
AT OLD SPRINKLE ROAD

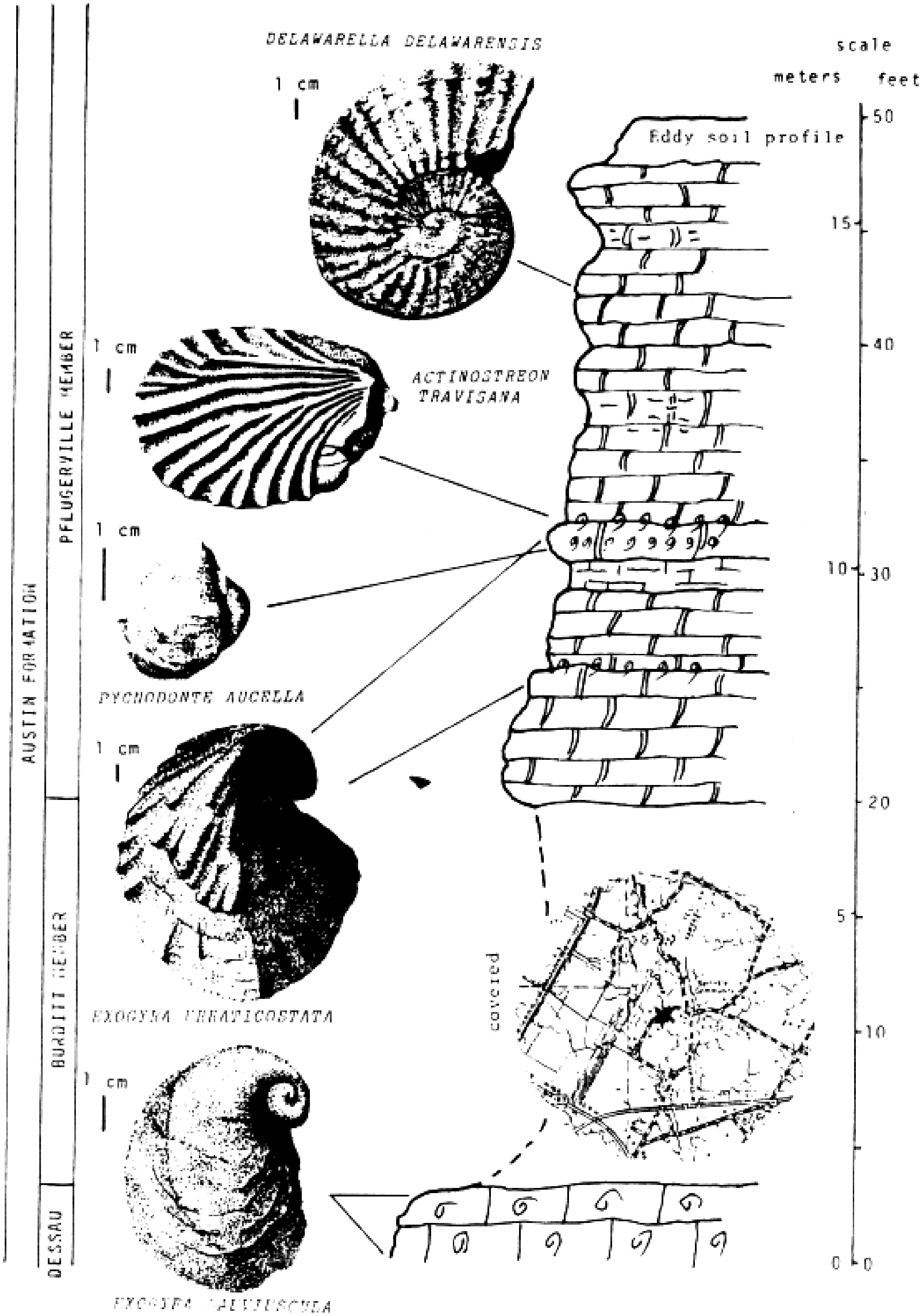


FIGURE 33

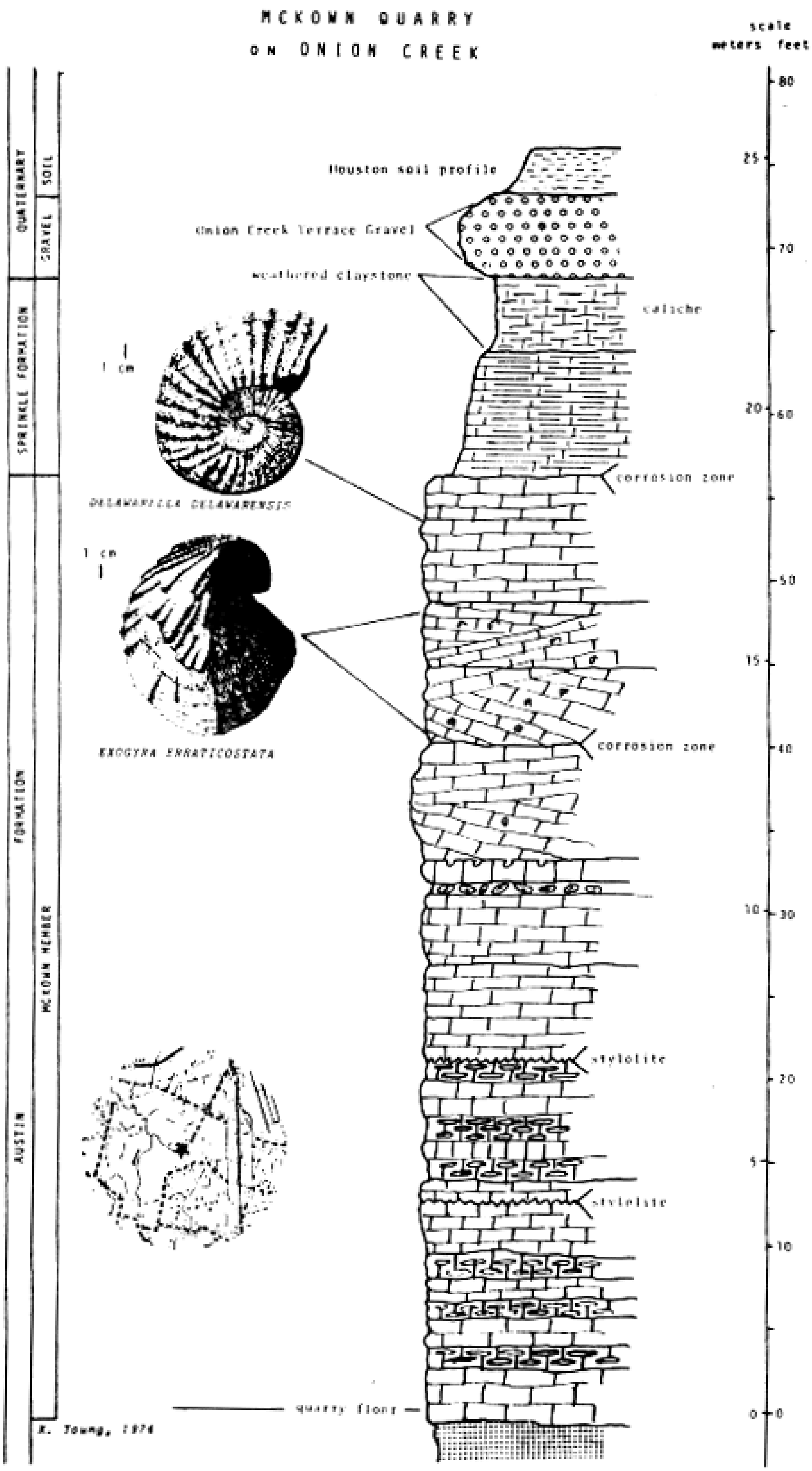

MCKOWN QUARRY
ON ONION CREEK
scale
meters feet
Houston soil profile
Onion Creek Terrace Gravel
weathered claystone
caliche
corrosion zone
DELAWARELLA DELAWARENSIS
EXOGYRA ERRATICOSTATA
corrosion zone
stylolite
stylolite
quarry floor
1 cm
1 cm
QUATERNARY
SOIL
GRAVEL
SPRINKLE FORMATION
AUSTIN FORMATION
MCKOWN MEMBER
K. Young, 1974

FIGURE 34

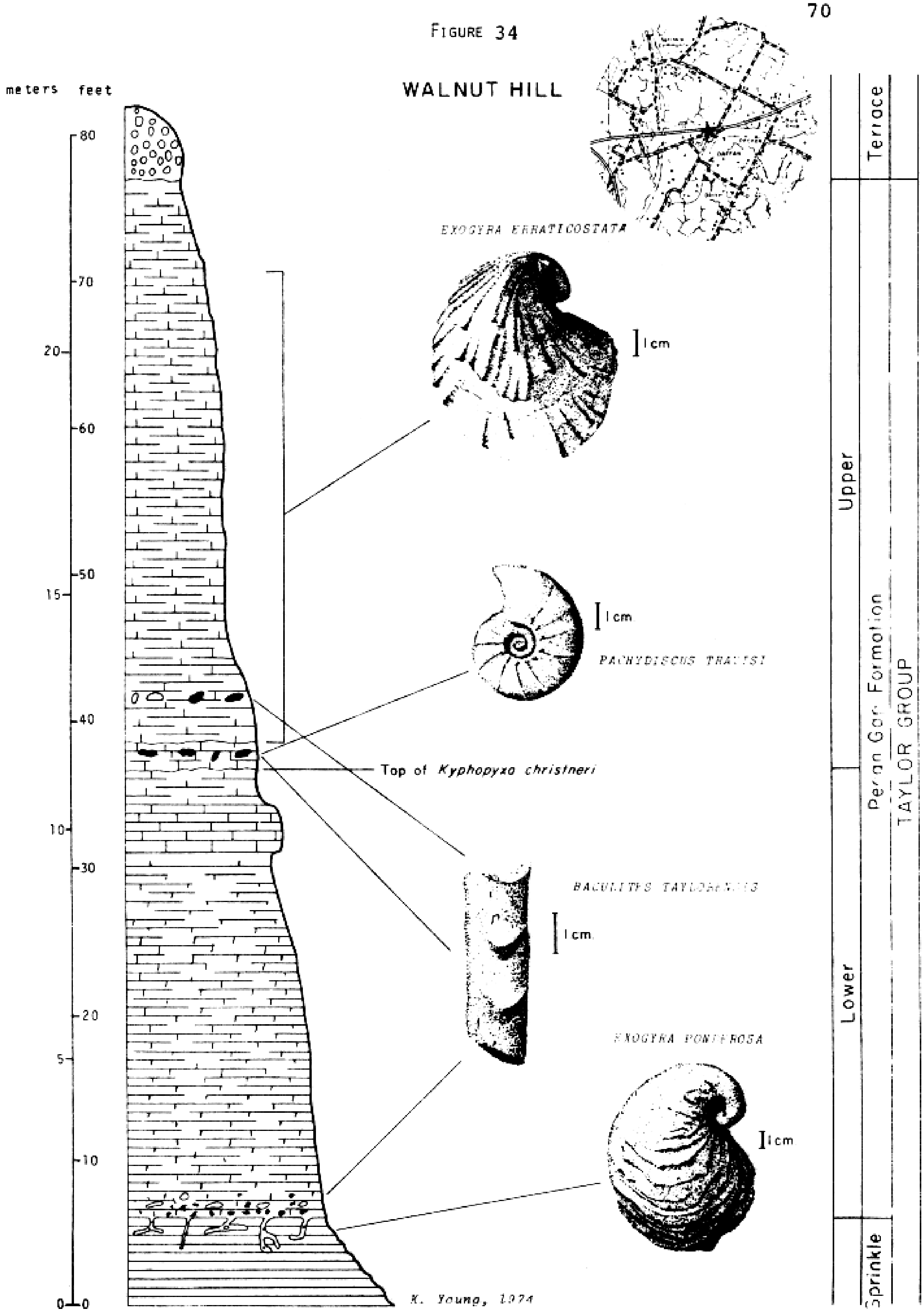
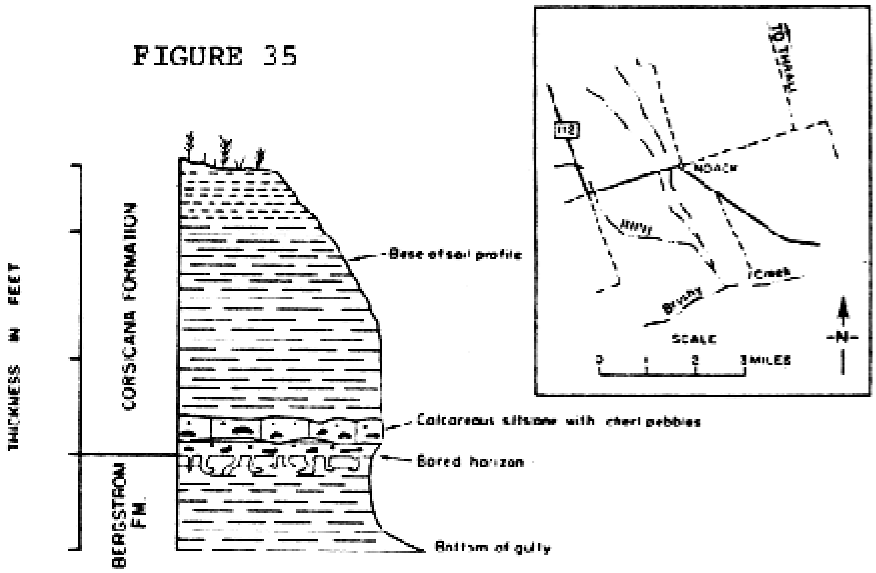

WALNUT HILL
meters feet
80
70
20
60
50
15
40
10
30
20
5
10
0 0
EXOGYRA ERRATICOSTATA
1 cm
1 cm
PACHYDISCUS TRAVISI
Top of Kyphopyxa christneri
1 cm
1 cm
EXOGYRA PONDEROSA
K. Young, 1974
Terrace
Upper
Lower
Sprinkle
Pecan Gap Formation
TAYLOR GROUP

FIGURE 35



Bergstrom-Corsicana boundary once exposed 7/8 mile west of Noack, Williamson County, Texas. From Young, 1965, figure 3.

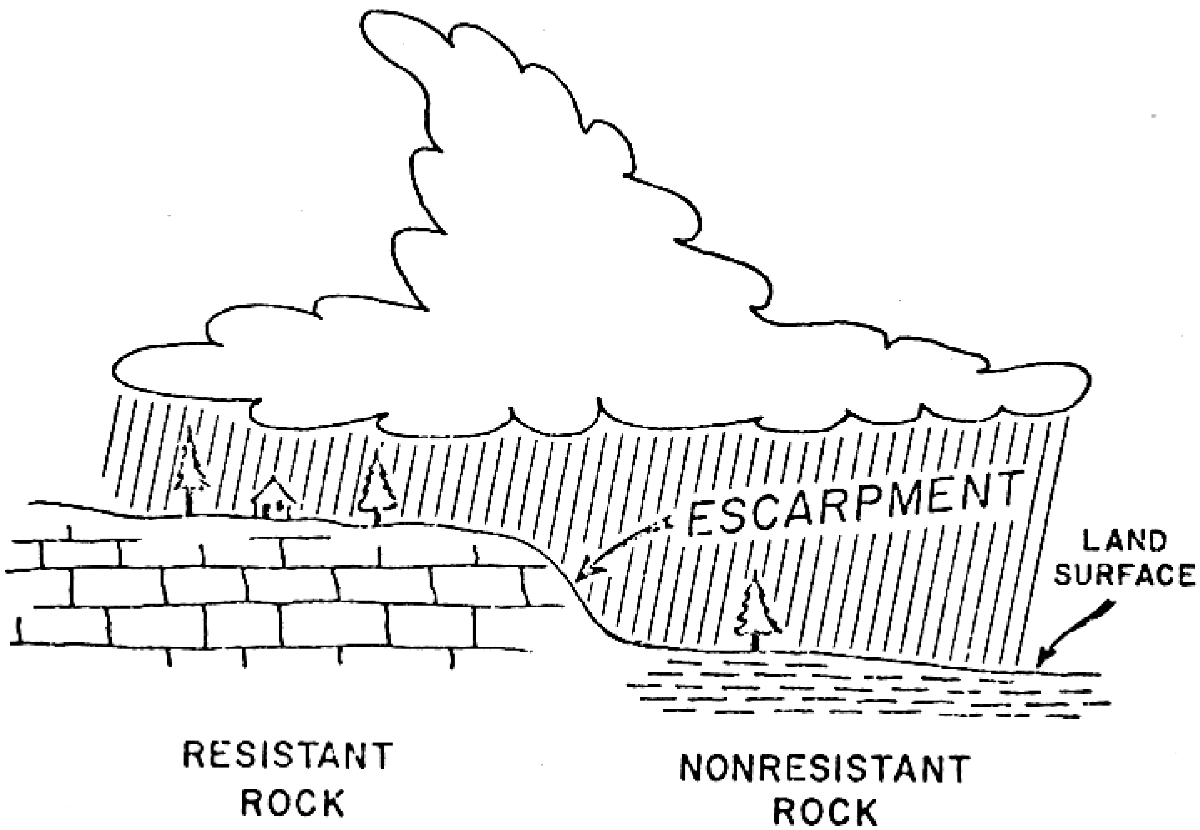


FIGURE 36
Profile of an Erosional Escarpment

UNIT NAME	THICKNESS (FEET)	LITHOLOGY	RELATIVE RESISTANCE TO EROSION ▨ = RESISTANT ▢ = NONRESISTANT
AUSTIN GROUP	1000+	"SOFT" LIMESTONE	
EAGLE FORD	30	"SOFT" LIMESTONE	
BUDA	40	LIMESTONE	
DEL RIO	60	CLAY	
GEORGETOWN	80	LIMESTONE	
EDWARDS	250	LIMESTONE	
WALNUT	70	FOSSILIFEROUS CLAY	
GLEN ROSE	690	LIMESTONE	

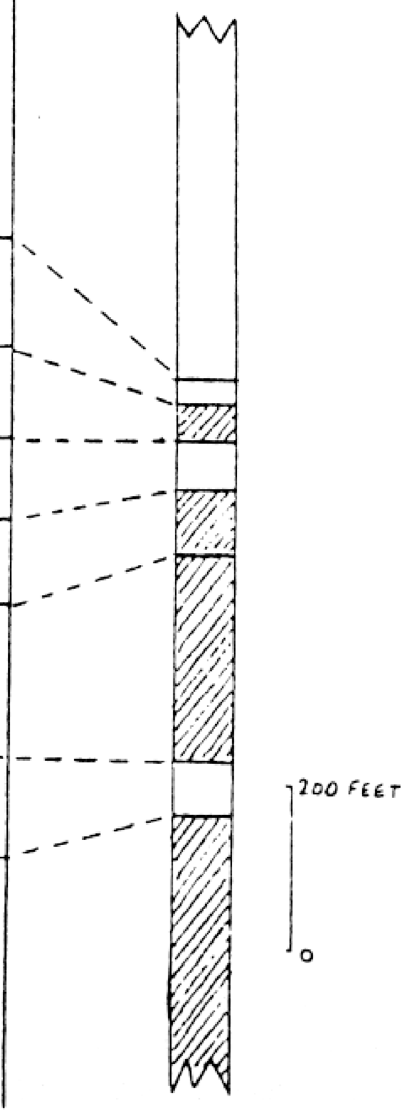


FIGURE 37
Relative Resistance to Erosion of Rock Units Exposed in the Austin Area (M.A. Jordan)

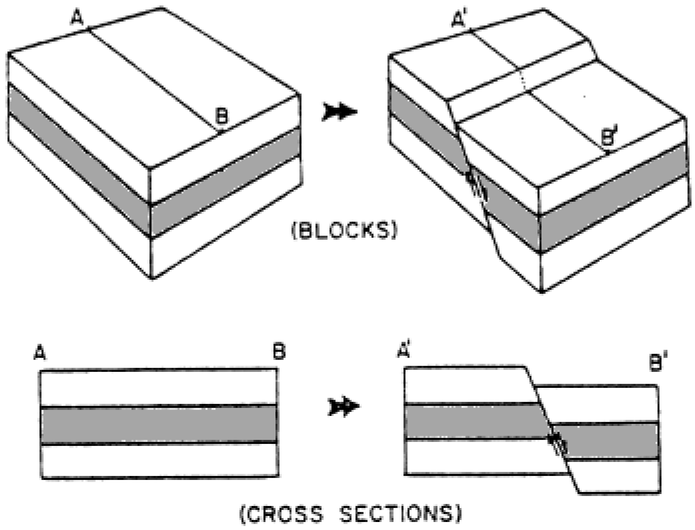


FIGURE 38

A Fault -
Before and After (M.A. Jordan)

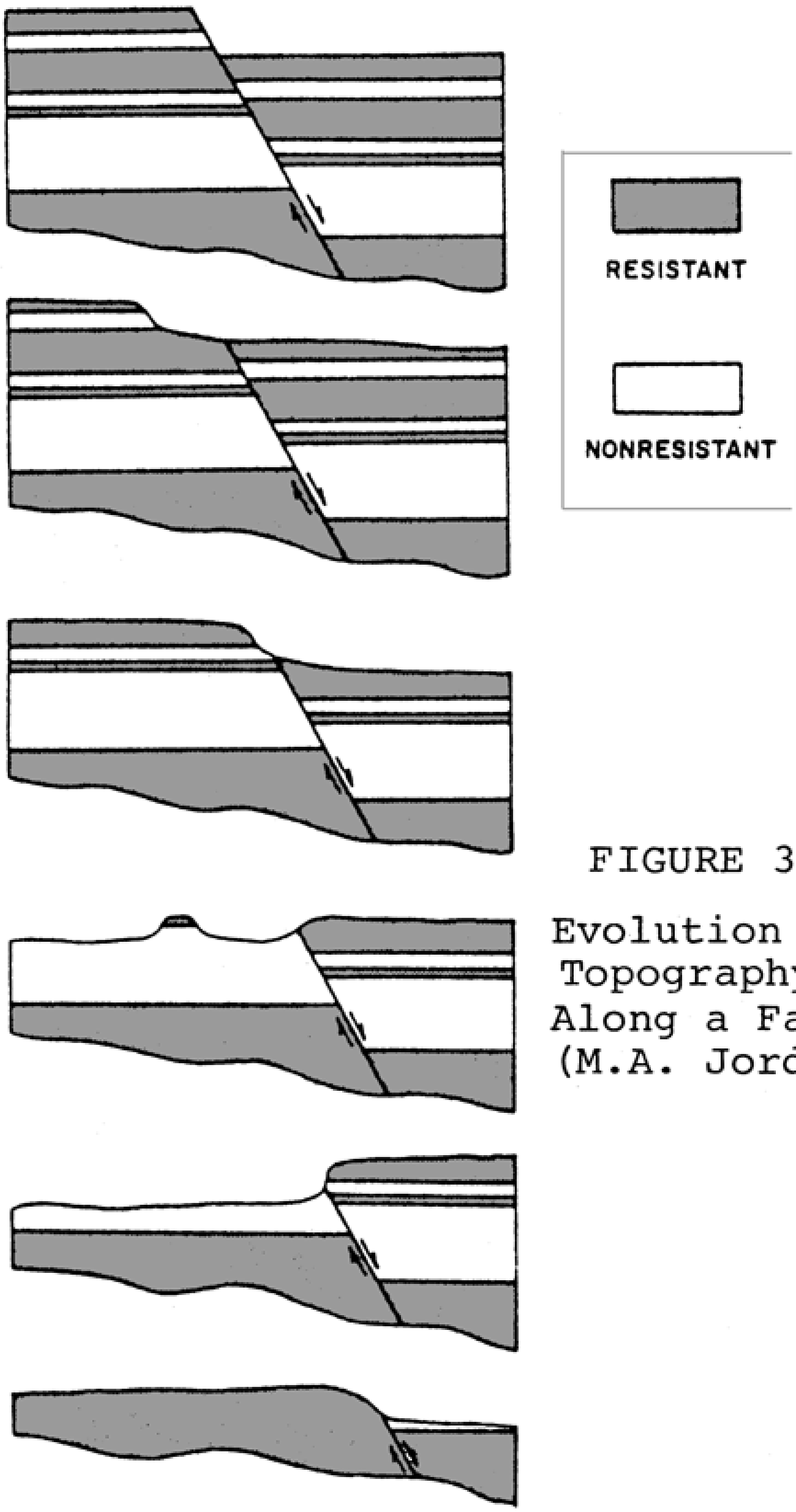
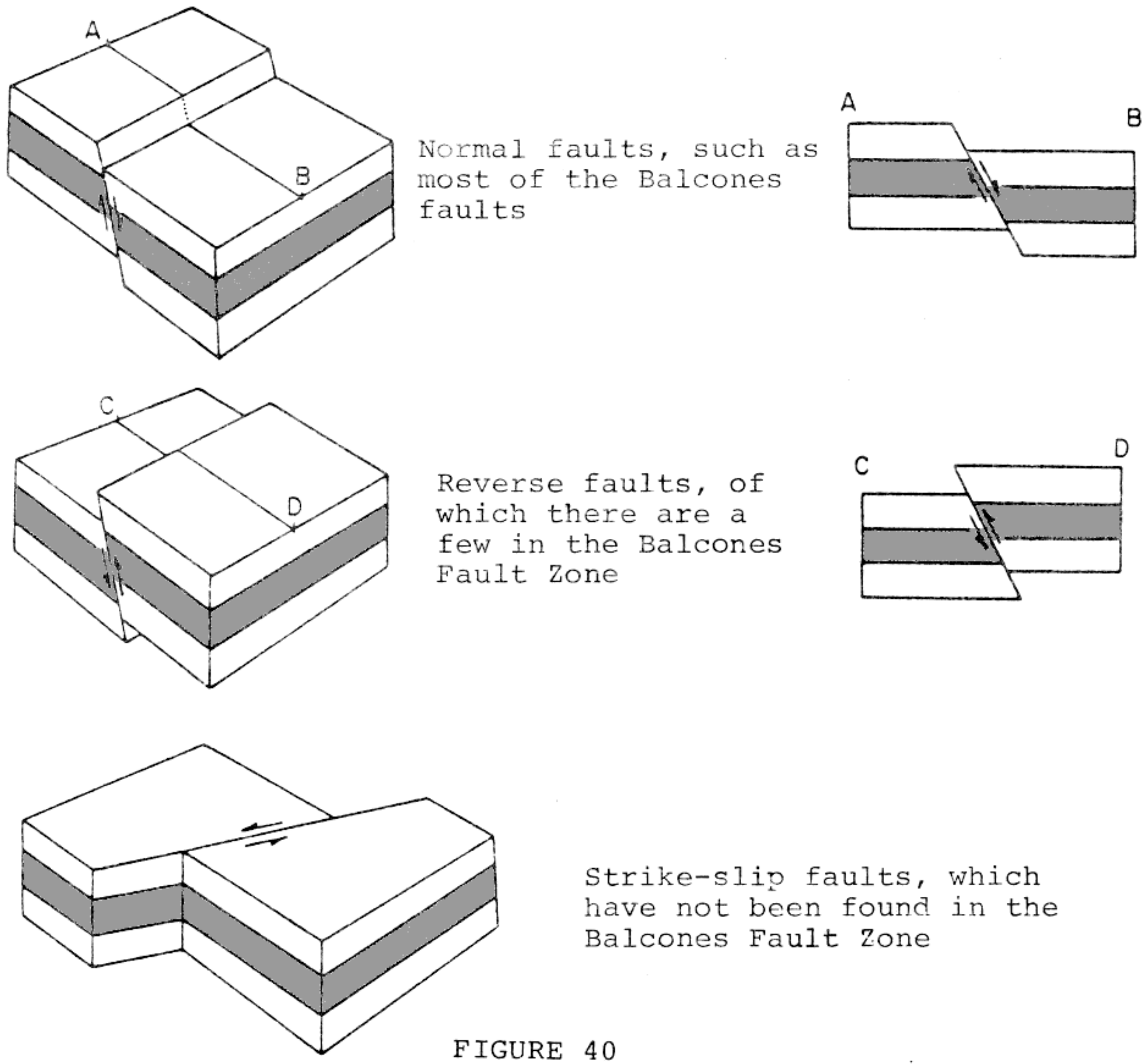


FIGURE 39

Evolution of
Topography
Along a Fault
(M.A. Jordan)



Normal faults, such as most of the Balcones faults

Reverse faults, of which there are a few in the Balcones Fault Zone

Strike-slip faults, which have not been found in the Balcones Fault Zone

FIGURE 40
Classification of Fault Types (M.A. Jordan)

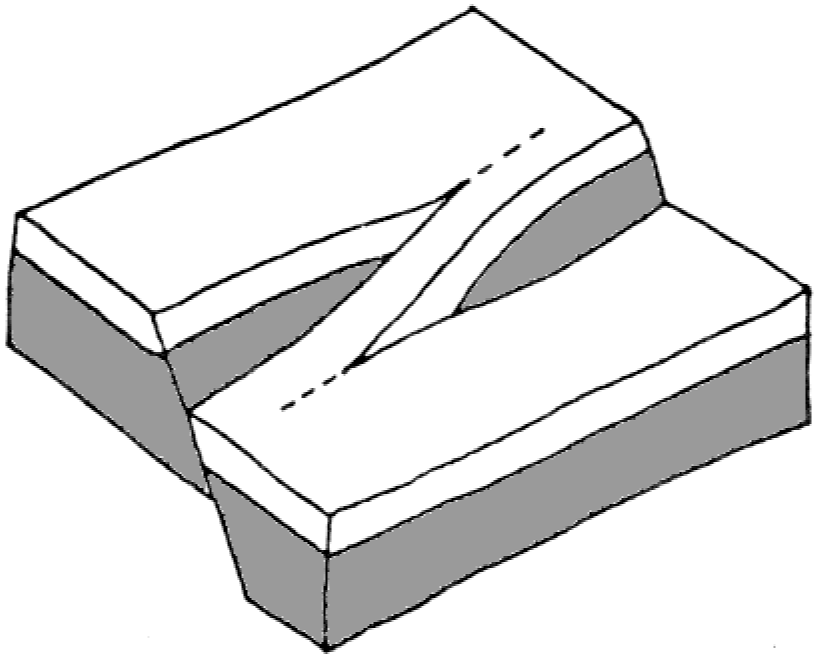


FIGURE 41
Sharing of Displacement
of a Fault (M.A. Jordan)

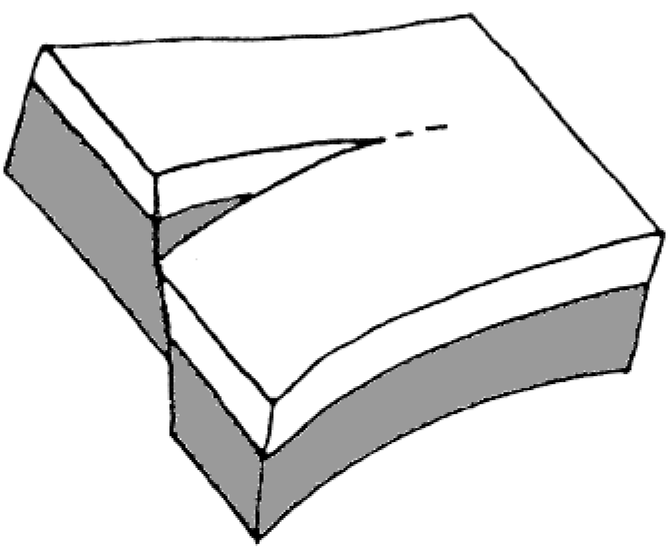


FIGURE 42
"Dying-out" of a
Fault (M.A. Jordan)

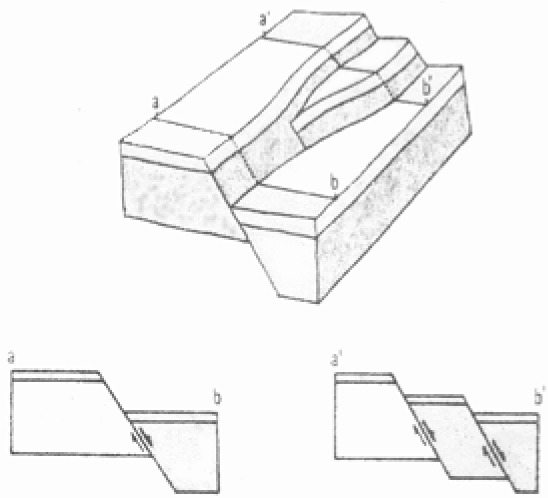


FIGURE 43

Joining (or Splitting) of a Fault (M.A. Jordan)

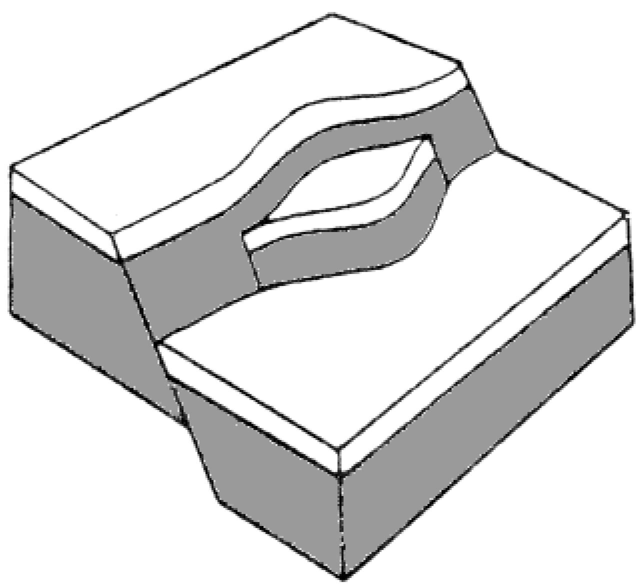


FIGURE 44

A Drag-block (M.A. Jordan)

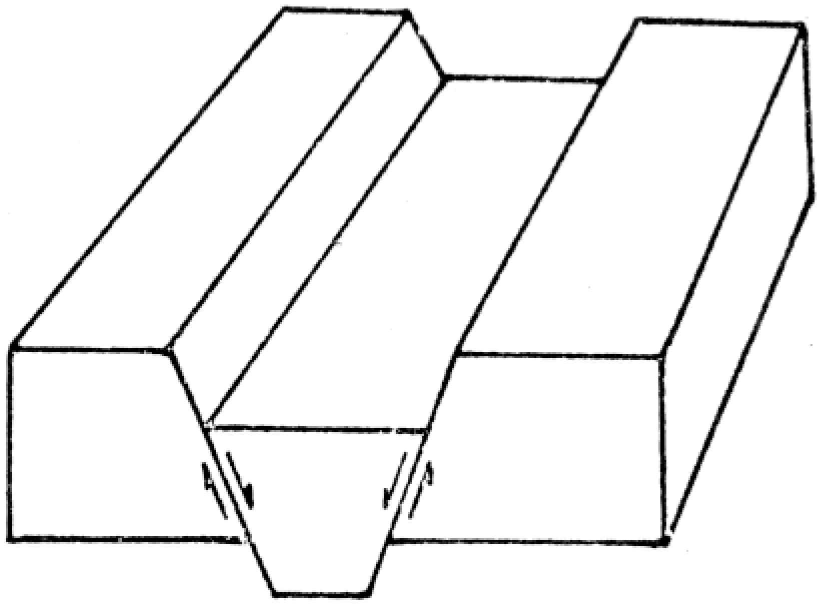


FIGURE 45
A Graben (M.A. Jordan)

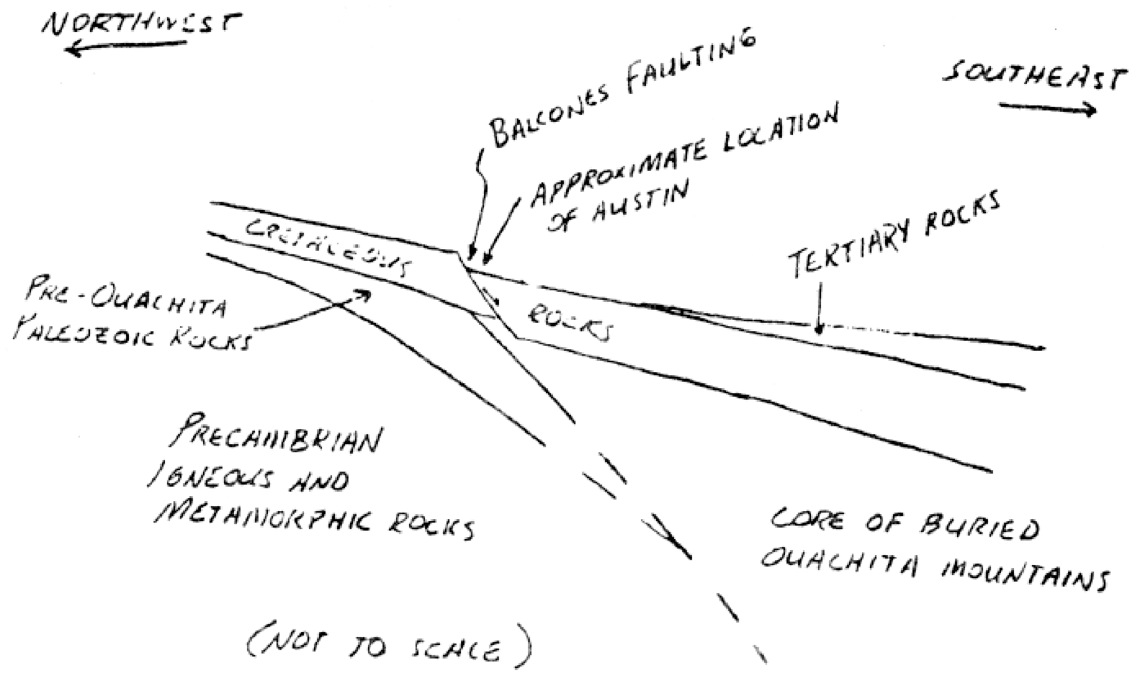


FIGURE 46

Cross-sectional Sketch of Subsurface Relations in Austin Area (M.A. Jordan)

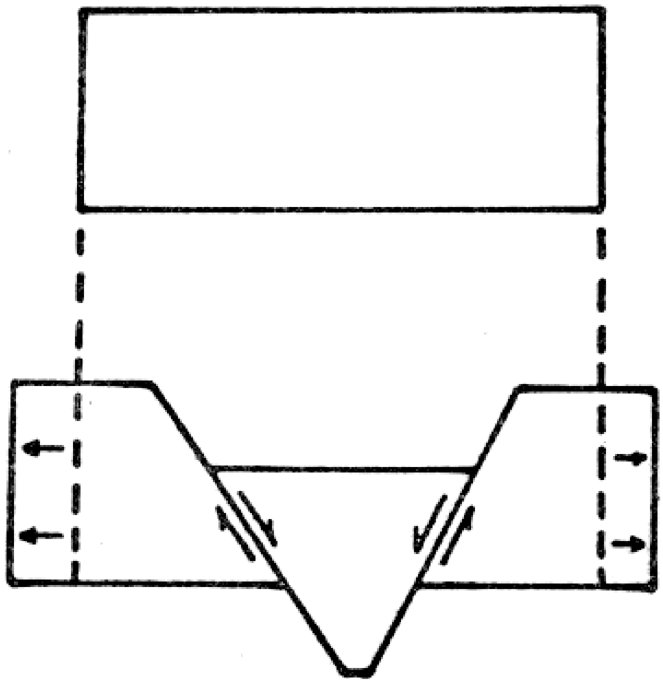


FIGURE 47

Extensional Origin of Graben (M.A. Jordan)

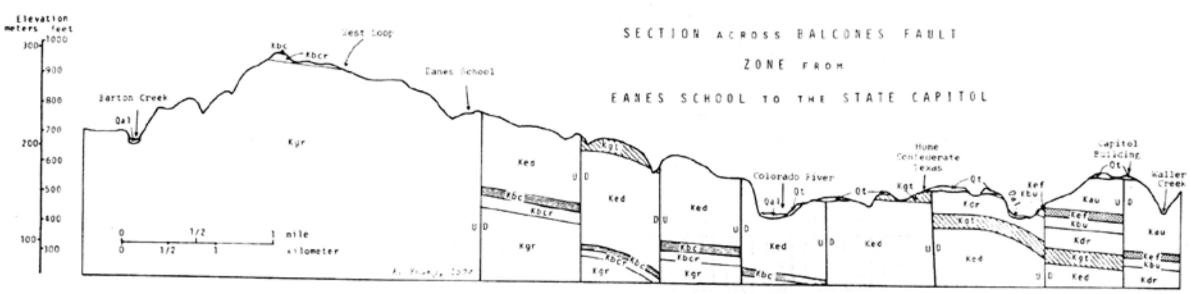


FIGURE 48

Cross-section Through Balcones Fault Zone

91

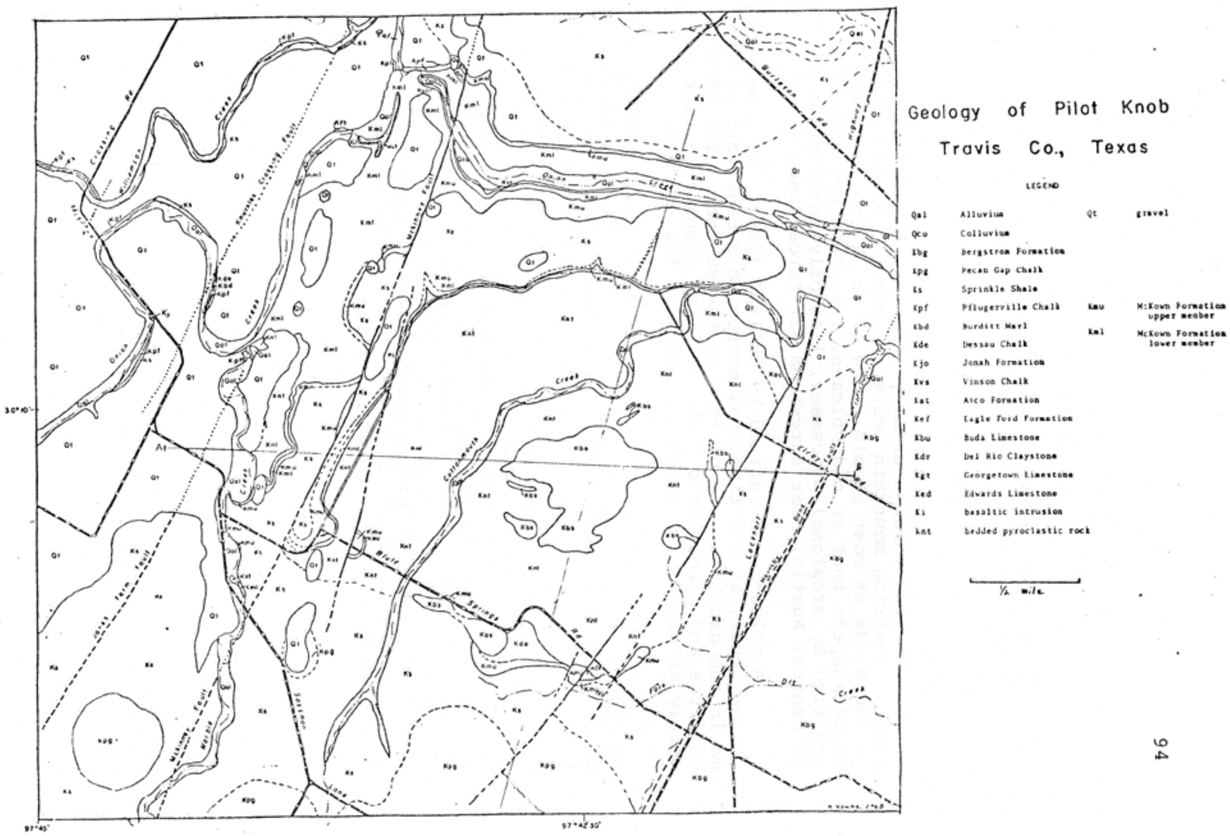
Legend

Qal	alluvium
Qt	terrace gravel
Kau	Austin Chalk
Kef	Eagle Ford Formation
Kbu	Buda Limestone
Kdr	Del Rio Claystone
Kgt	Georgetown Limestone
Ked	Edwards Limestone
Kbc	Bee Cave Marl
Kbcr	Bull Creek Limestone
Kgr	Glen Rose Limestone

FIGURE 49

Legend to the Structural Cross-section in Fig. 48

FIGURE 50 - Geologic Map of the Pilot Knob Complex



94

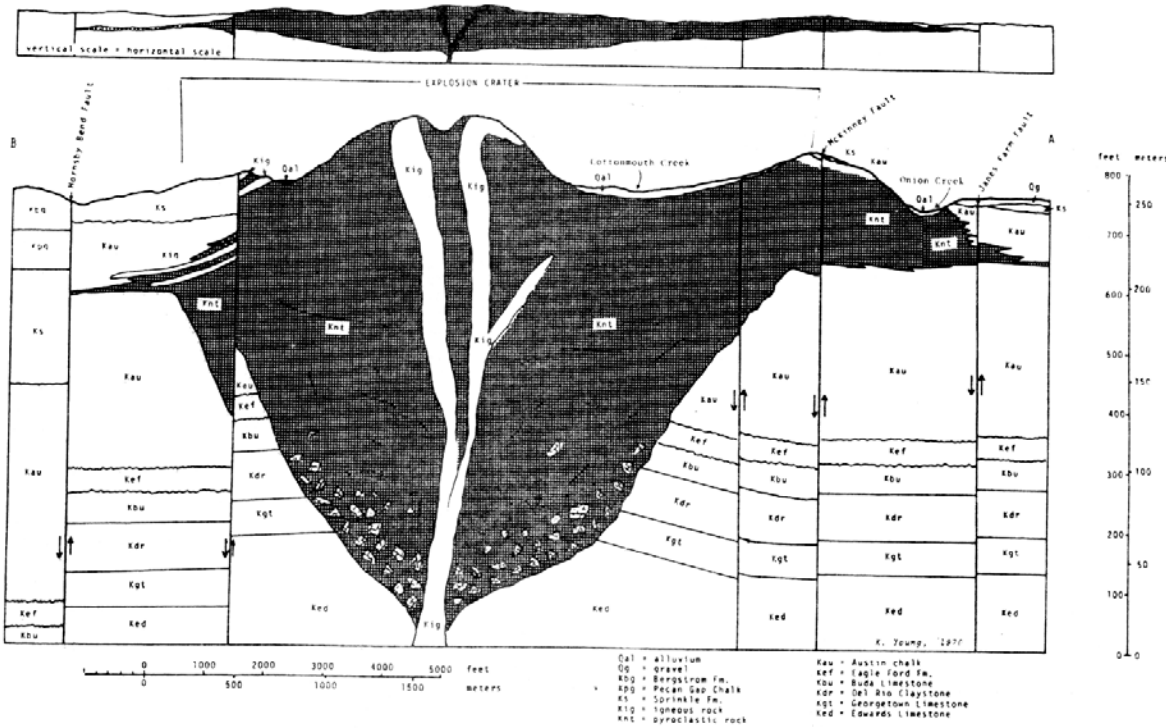


FIGURE 51

North-South Section Through Pilot Knob

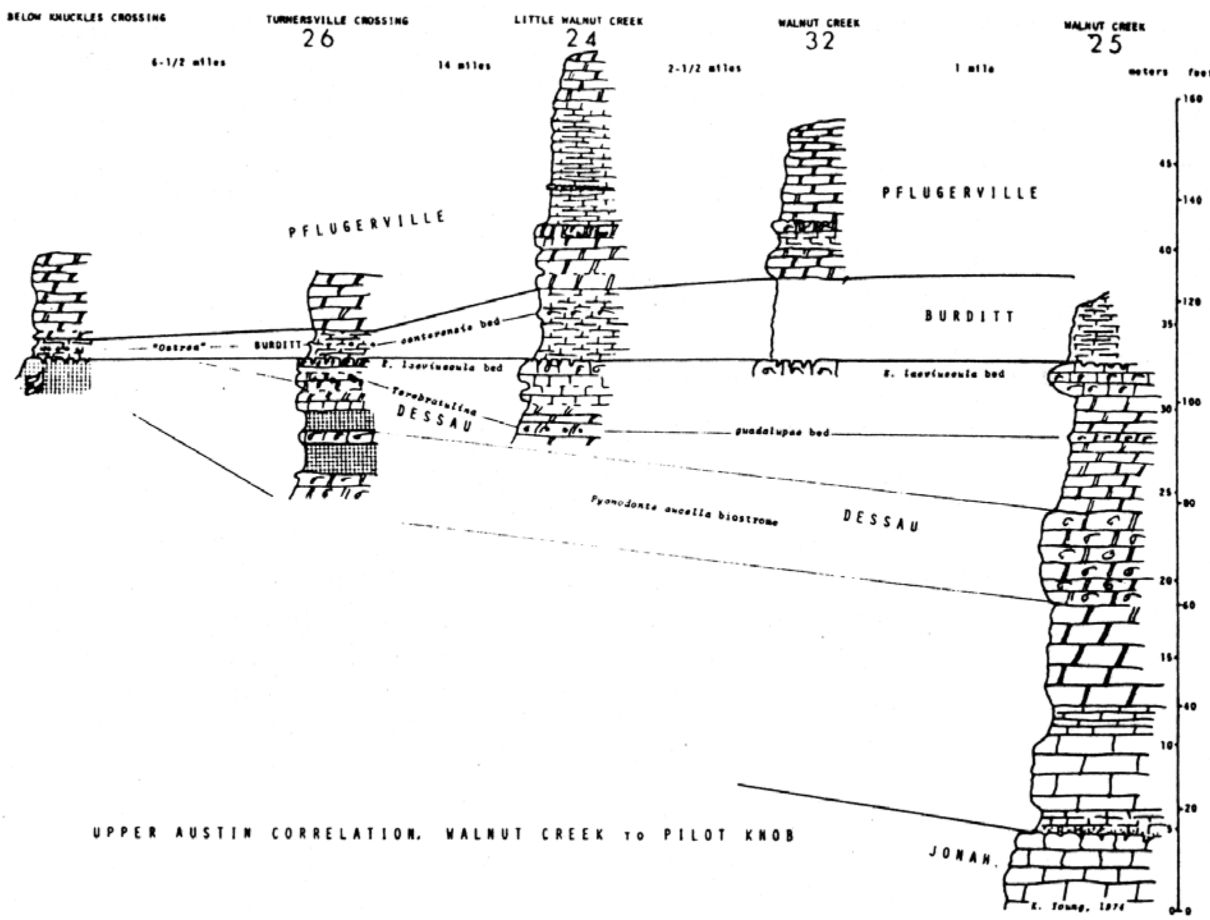


FIGURE 52
North-South Stratigraphic Correlation Through Austin

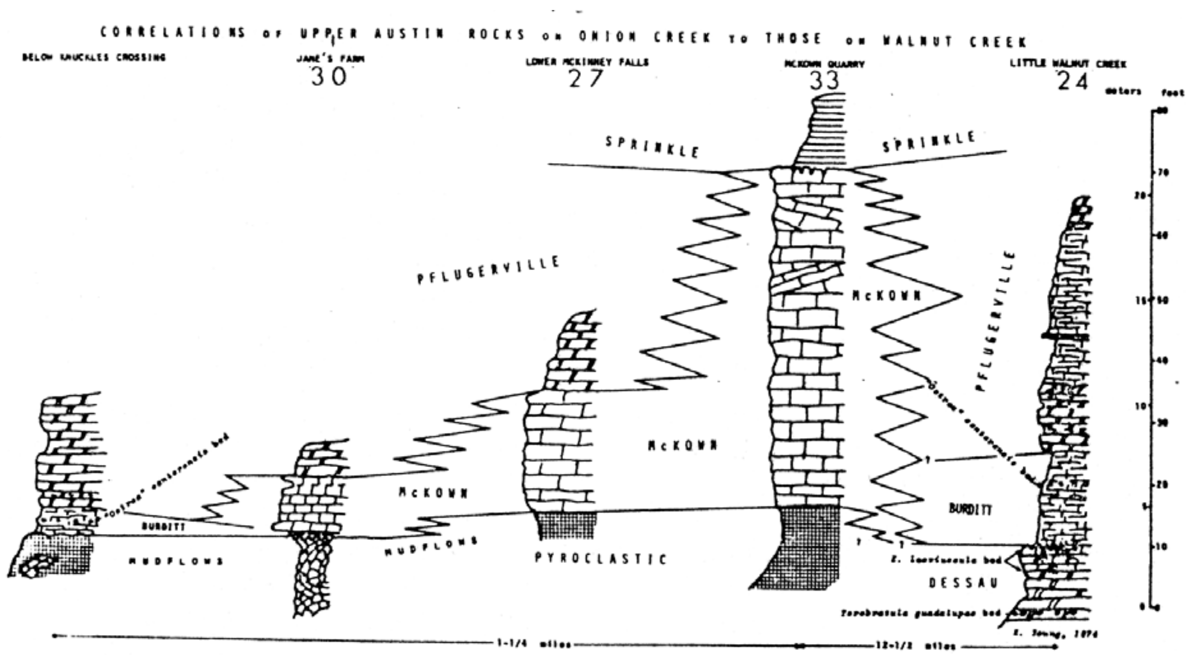


FIGURE 53
East-West Stratigraphic Correlation just North of Pilot Knob Vicinity